Introduction to Piping engineering

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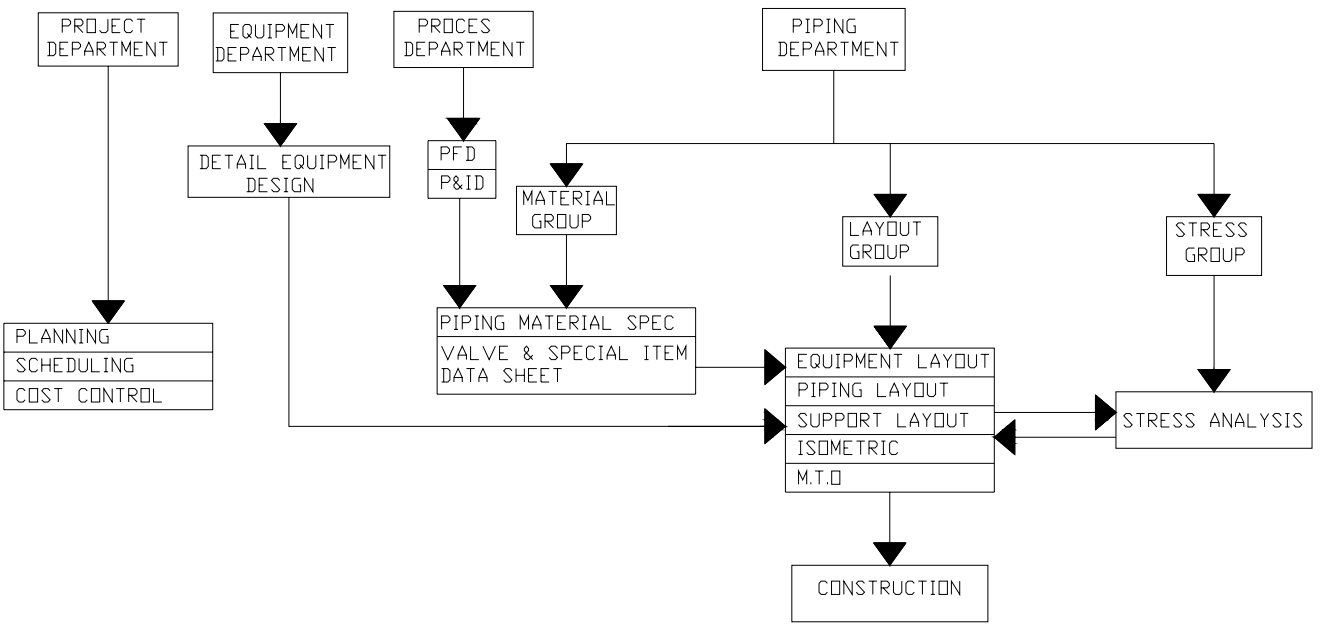
OVERVIEW OF AN ENGINEERING DESIGN ORGANIZATION



ROLE OF PIPING ENGINEER.

- Design
- Construction
- Commissioning
- Operation

RESPONSIBILITY OF PIPING ENGINEER.

- Piping engineer is responsible for accurate design
- Piping design must satisfy the P&ID & specification constraints.
- Standardization of engineering design method.
- To achieve adequate design at an economic cost.
- To co-ordinate with other departments.
- Co-ordination with the site.

- Much of the piping data is used by other engineering group so it must be correct, clear, consistent & reliable.
- To complete the project within the planned completion period.

WHAT PIPING ENGINEERING SHOULD KNOW ABOUT.

- A piping engineer should have good knowledge about industrial process, mechanical, civil, electrical & instrumentation so as to discuss & understand the problem with the specialist.
- A piping engineer should have good knowledge of materials.
- A piping engineer should have good understanding of engineering economics & cost of method of pipe fabrication & erection.
- A piping engineer should have good knowledge of international codes & standards.
- Piping engineer should be well conversant with drafting procedures & practices.

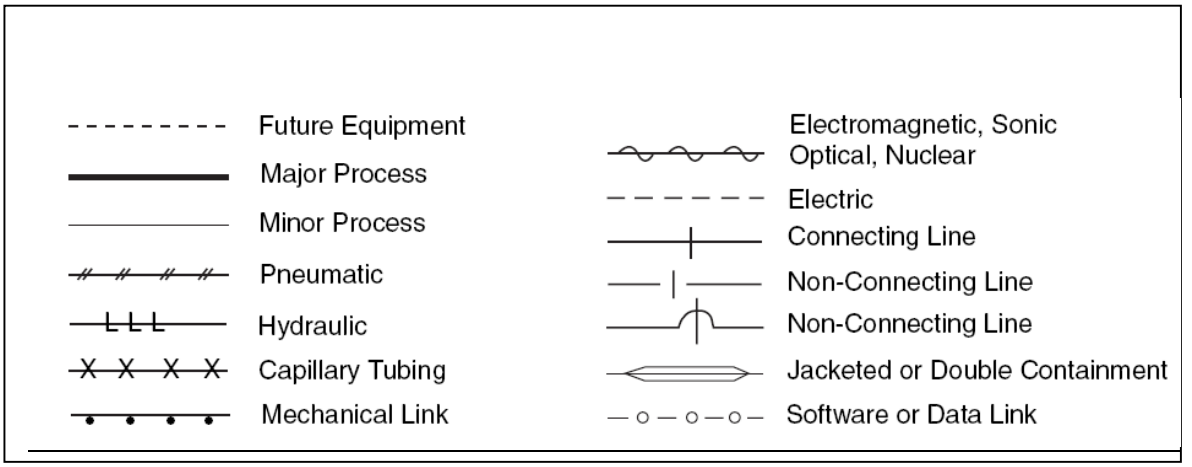
INPUTS TO PIPING.

- PFD, P&ID, Process description, Line list, Equipment list, Site data, Licensor etc.
- Instrument & cable tray width on pipe rack.
- Equipment data sheet.
- Anchor bolt drawing.
- Civil information drawings.
- Vendor drawing of package drawings.
- Architectural drawings of all process & non-process buildings.
- Instrument hook-up drawing.
- HVAC ducting layout.

OUTPUT FROM PIPING.

- Plot plan
- Piping material class
- Equipment layout
- General arrangement of pipe rack.
- Civil information drawings.
- Piping layout.
- Support layout.
- Nozzle orientation drawing.
- Vessel cleats location drawings.
- Isometric drawings.
- M.T.O

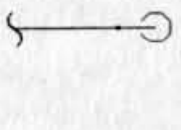
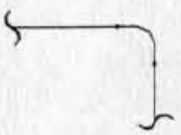
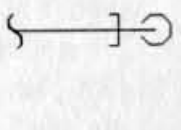
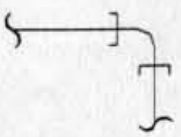
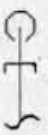
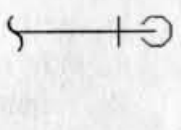
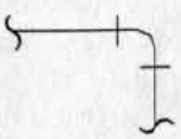
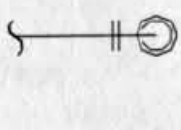
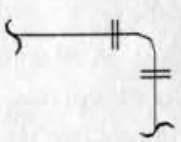
LEGEND. – A document used to define symbols, abbreviations, prefixes, and specialized equipment.



Piping Symbol

TABLE- I

PIPING SYMBOLS

Sr. No.	DESCRIPTION		PLAN	END VIEW 1	END VIEW 2
1.0	CHANGE OF DIRECTION AT 90°				
	1.1	DOWNWARD BENDING			
	1.1.1	BW elbow			
	1.1.2	SW elbow			
	1.1.3	Scrd elbow			
	1.1.4	Flgd elbow			
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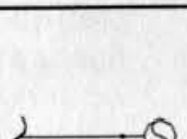
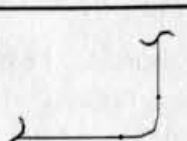
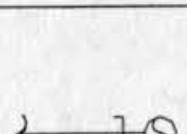
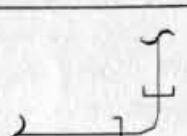
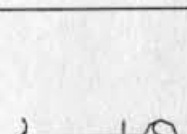
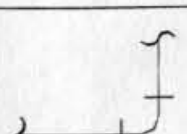
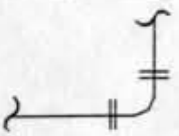
	1.2.1	BW elbow			
	1.2.2	SW elbow			
	1.2.3	Scrd elbow			

Sr. No.	DESCRIPTION	PLAN	END VIEW 1	END VIEW 2
1.0	CHANGE OF DIRECTION AT 90°			
1.2	UPWARD BENDING			
1.2.4	Flgd elbow			
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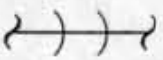
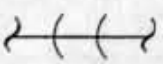
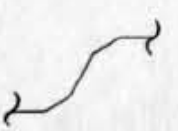
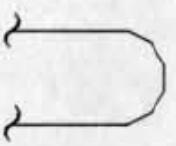
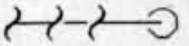
2.1	DOWNWARD BENDING			
2.2	UPWARD BENDING			
2.3	180° Returns			
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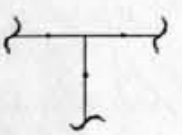
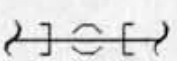
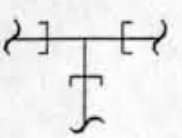
3.1	DOWNWARD			
3.1.1	BW Tee			
3.1.2	SW Tee			

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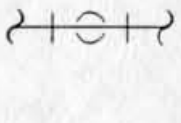
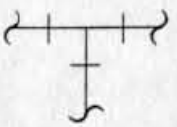
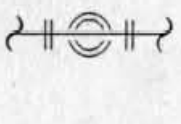
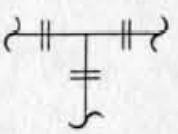
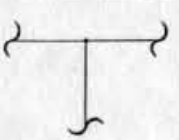
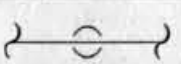
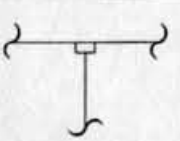
3.1.3	Scrd Tee			
3.1.4	Flgd Tee			
3.1.5	Stub connection			
3.1.6	Half Coupling			
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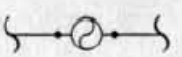
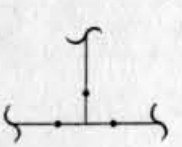
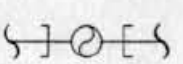
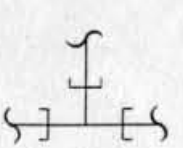
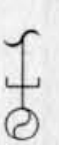
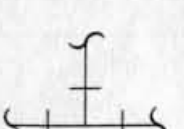
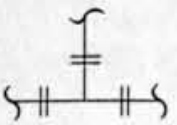
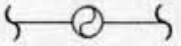
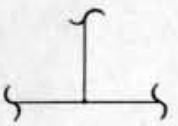
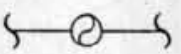
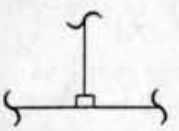
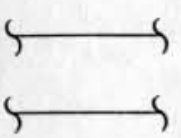
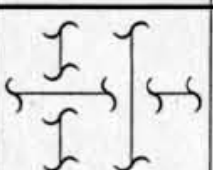
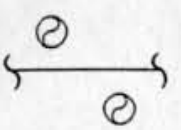
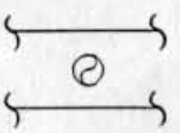
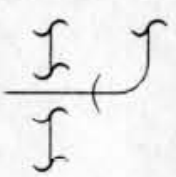
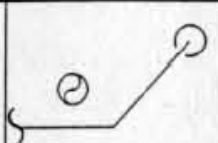
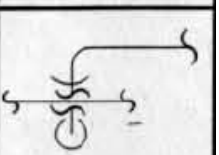
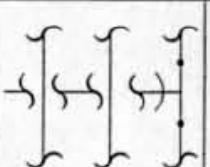
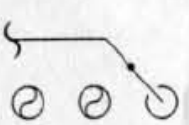
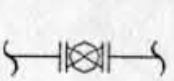
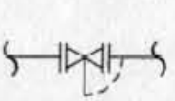
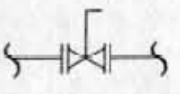
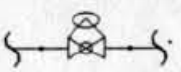
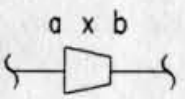
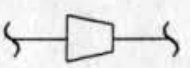
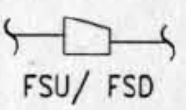
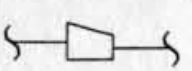
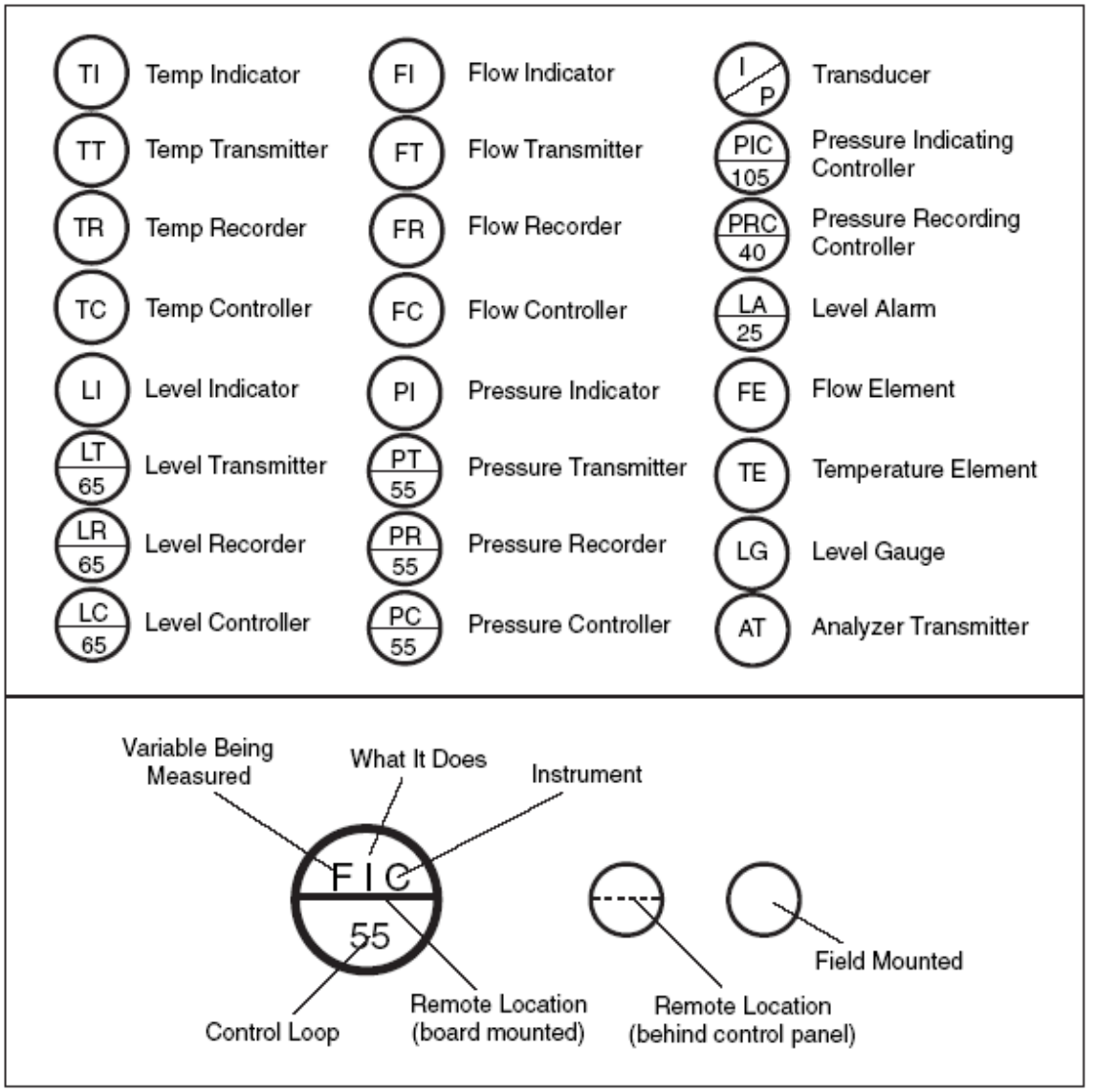
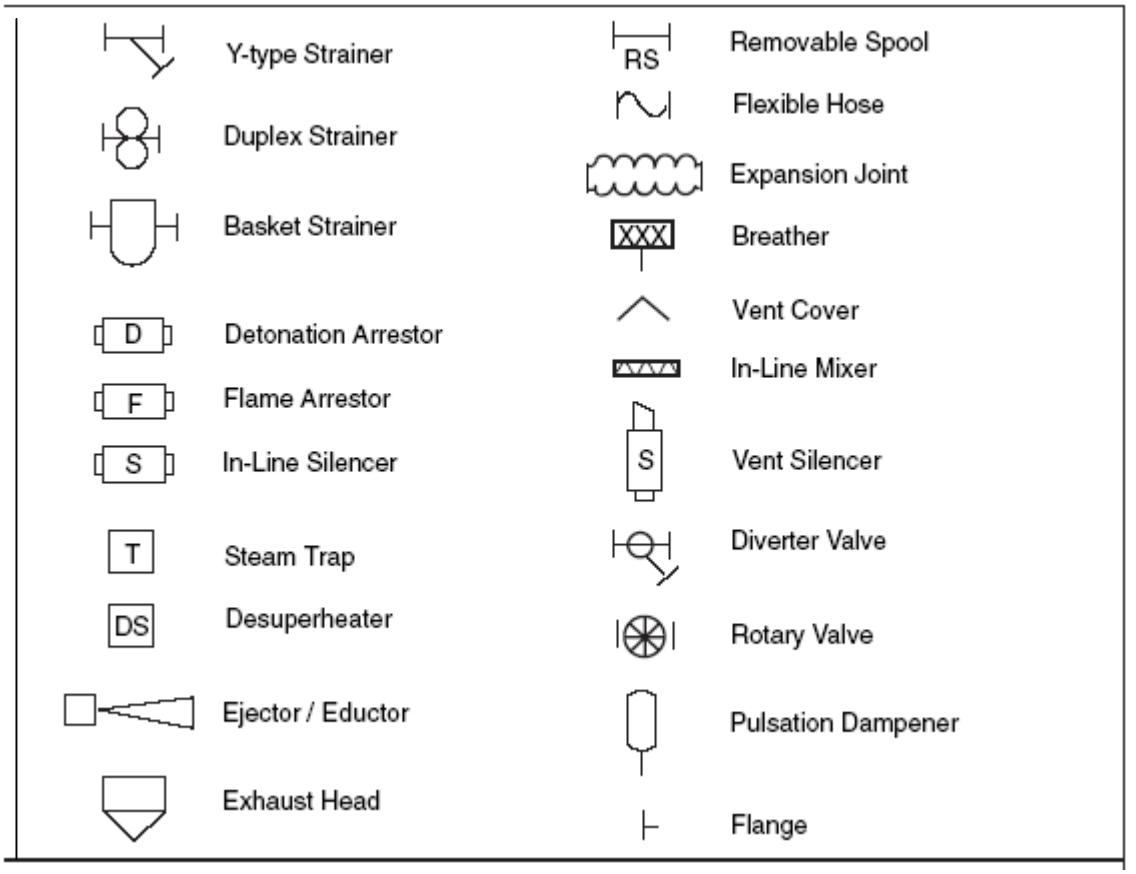
3.2.1	BW Tee			
3.2.2	SW Tee			
3.2.3	Scrd Tee			

Sr. No.	DESCRIPTION	PLAN	END VIEW 1	END VIEW 2
3.0	BRANCHING			
	3.2 UPWARD			
	3.2.4 Flgd Tee			
	3.2.5 Stub connection			
	3.2.6 Half Coupling			
4.0	PARALLEL LINES			
5.0	CROSS LINES			
6.0	ROLLED ELBOW			
7.0	ROLLED TEE			

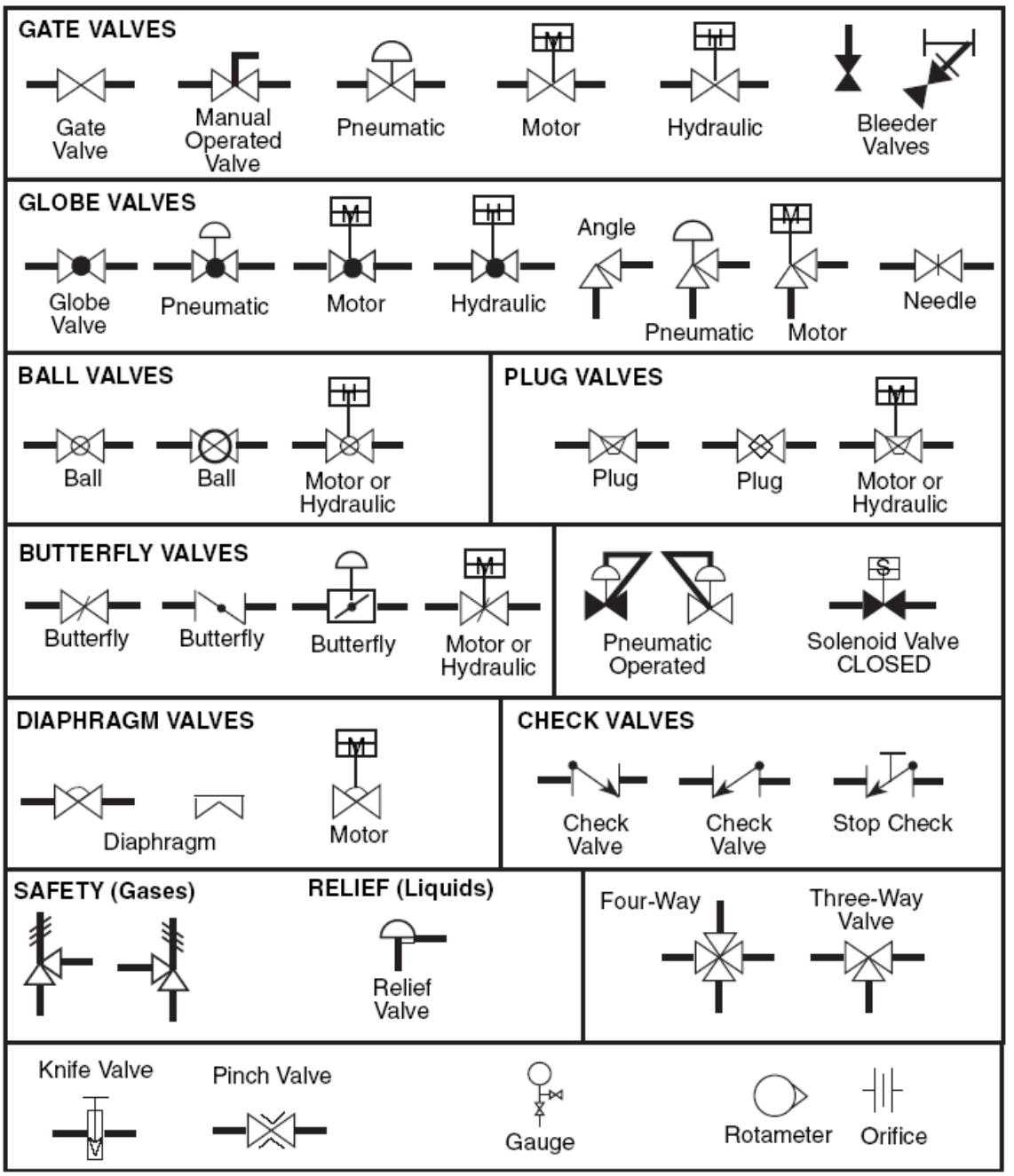
Sr. No.	DESCRIPTION	PLAN	END VIEW 1	END VIEW 2
8.0	VALVES			
	8.1 Hand Wheel Operated Flgd Valve with vertical hand wheel			
	8.2 Lever operated Valve			
	8.3 Hand wheel operated BW Valve with rolled hand wheel			
9.0	CONCENTRIC REDUCER			
10	ECCENTRIC REDUCER			



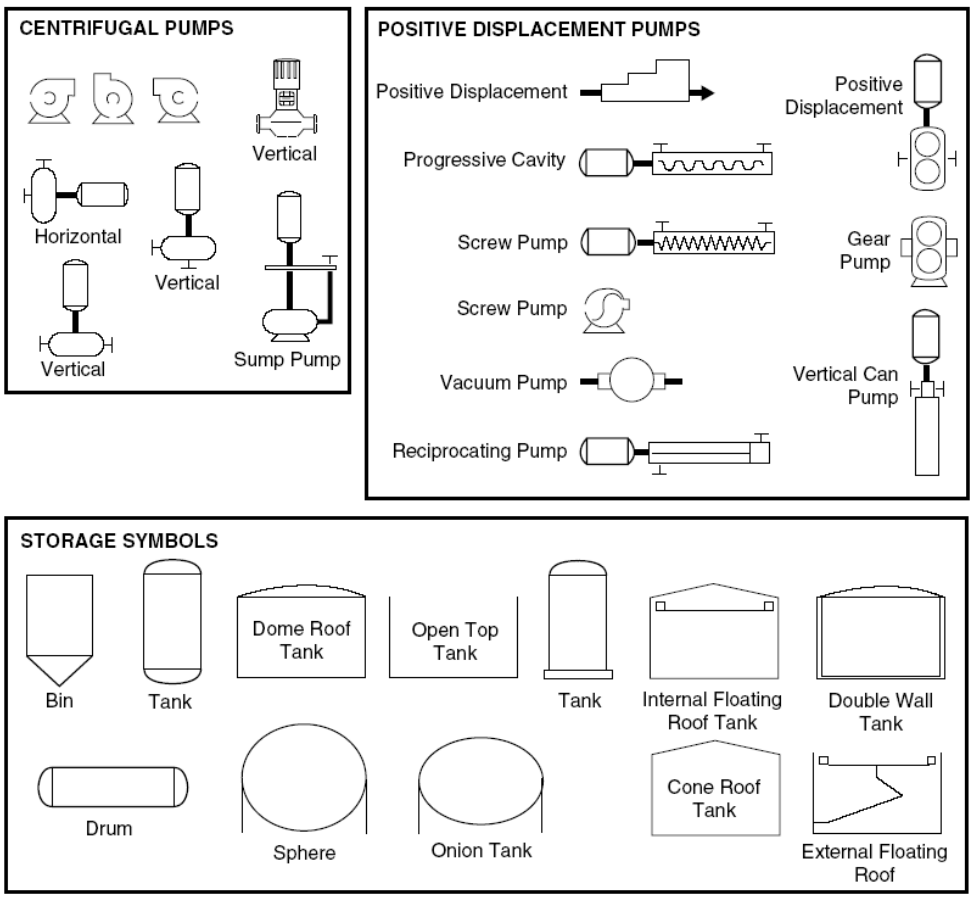
Process & instrument Symbol



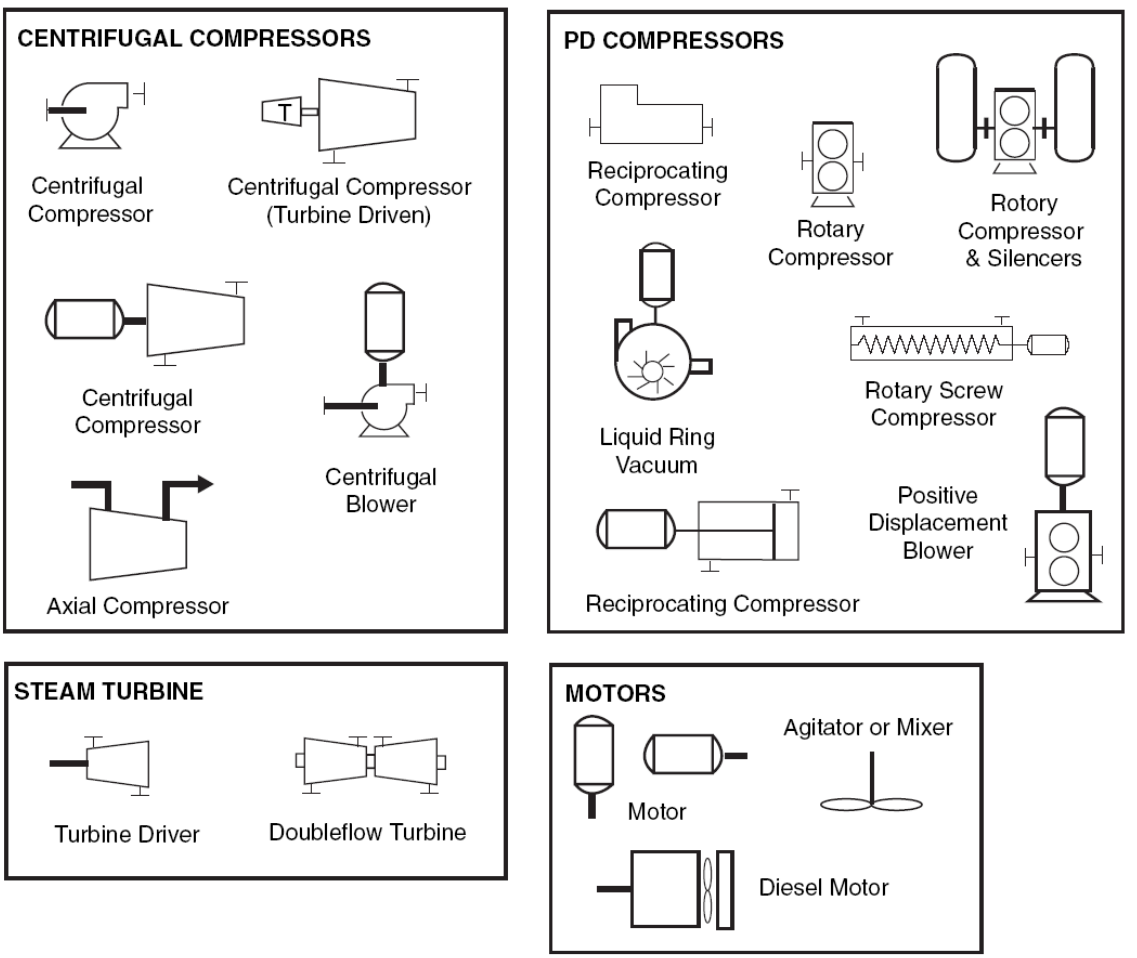
Piping Component Symbols



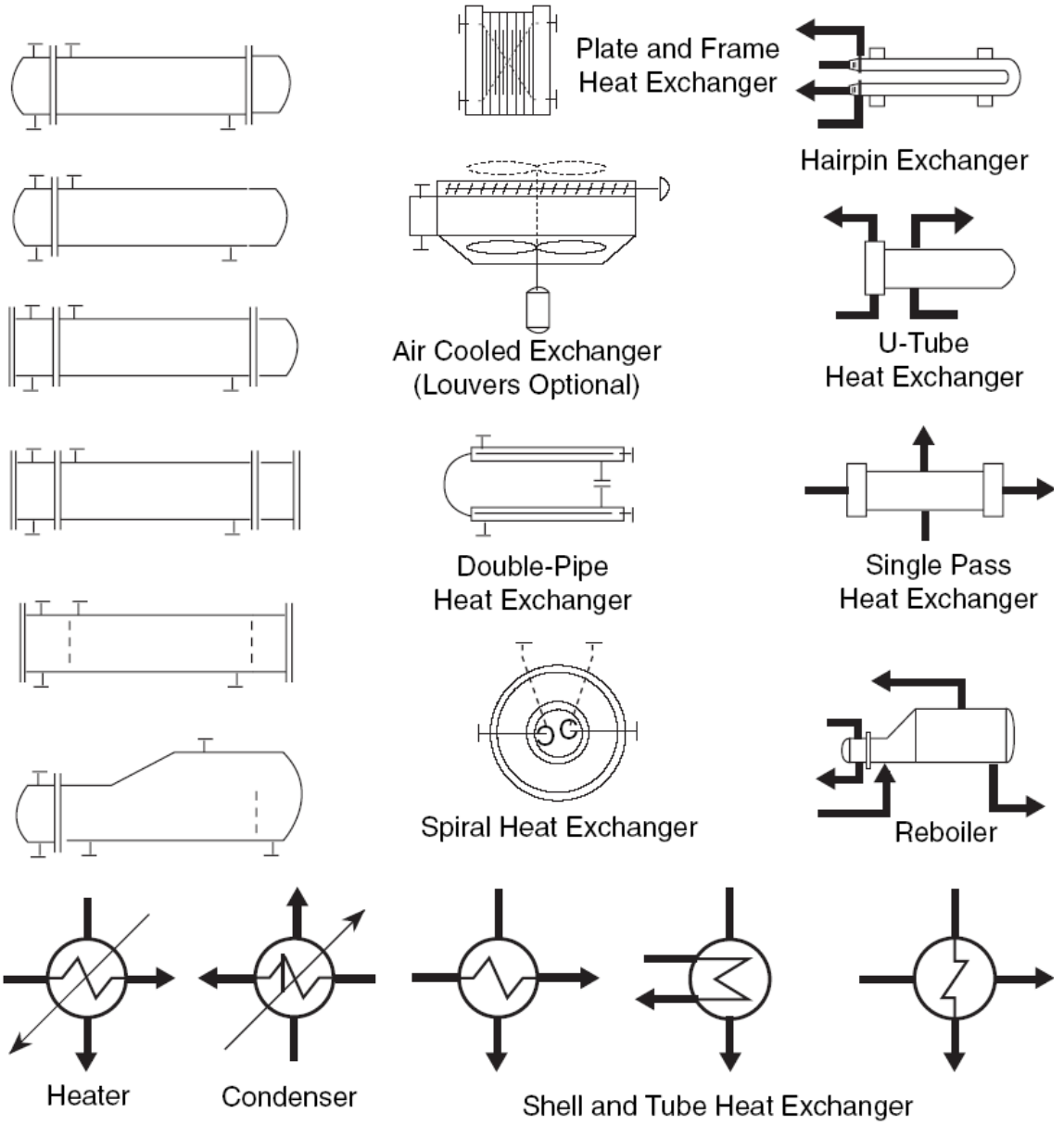
Valves Symbols



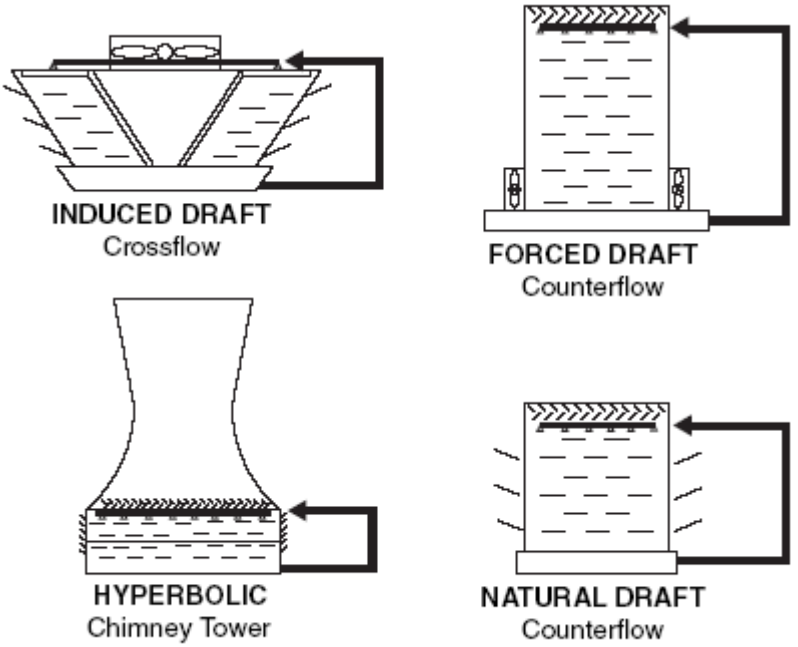
Pumps & Tanks Symbols



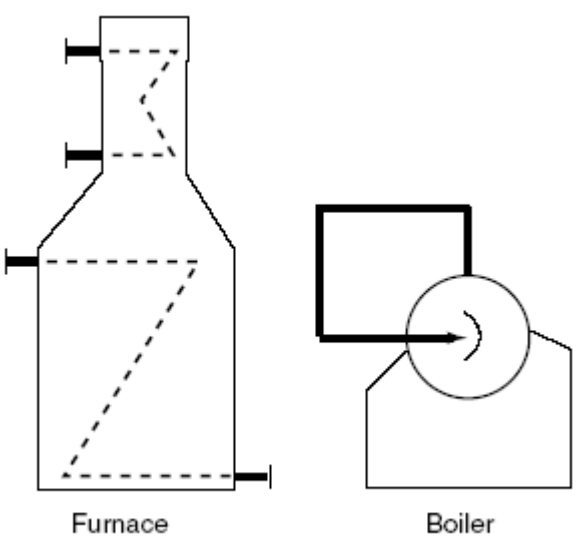
Compressor, Steam turbine & motors Symbols



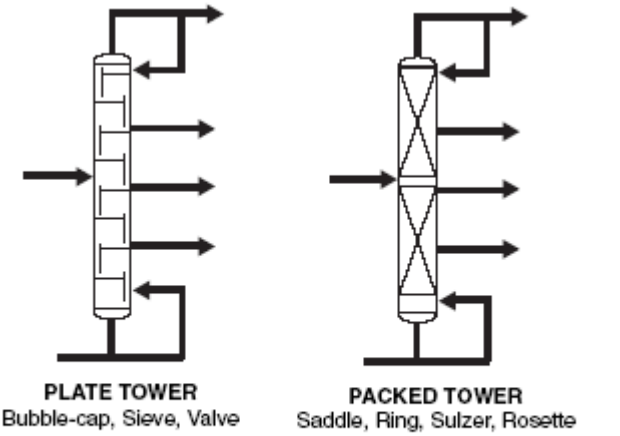
Heat Exchanger Symbols

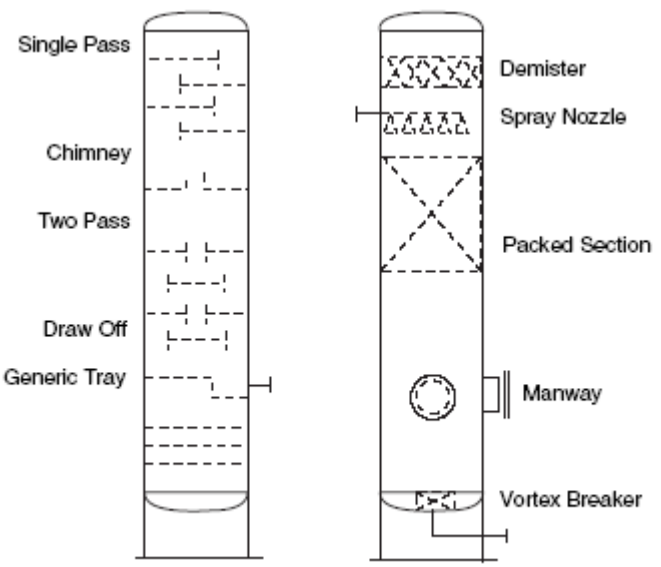


Cooling Tower Symbols

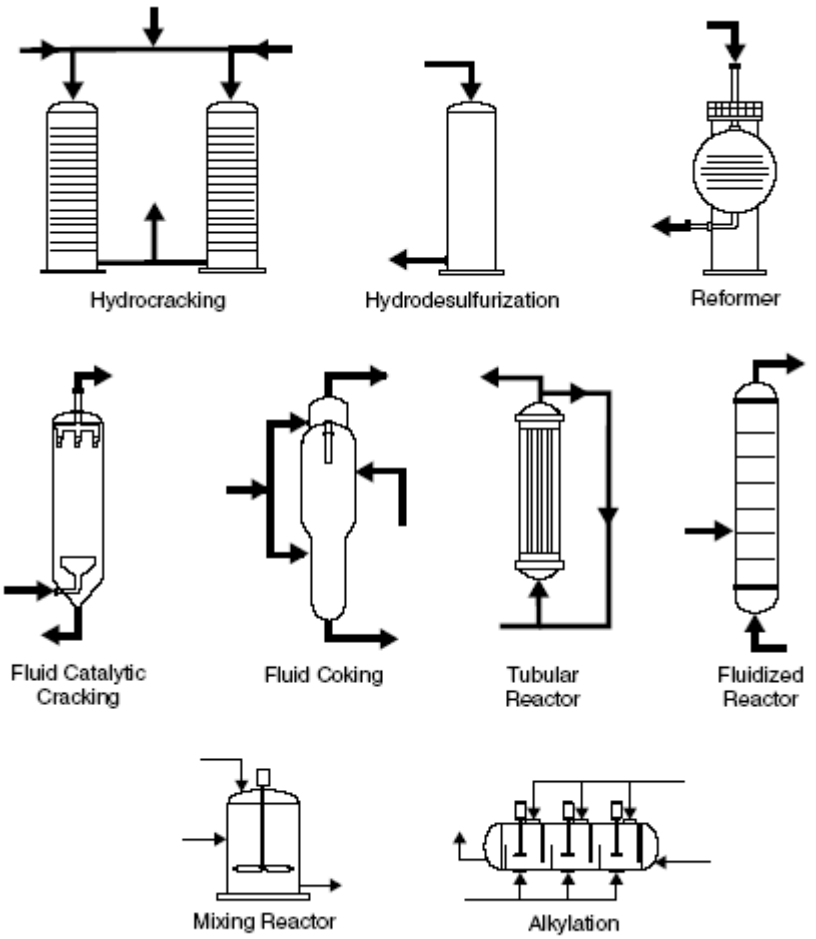


Furnace & boiler Symbols





Distillation column Symbols



Reactor Symbols

PIPING CODES & STANDARDS

The integrity of a piping system depends on the considerations and principles used in design, construction and maintenance of the system.

Piping systems are made of many components as pipes, flanges, supports, gaskets, bolts, valves, strainers, flexible and expansion joints.

The components can be made in a variety of materials, in different types and sizes and may be manufactured to common national standards or according a manufacturers proprietary item.

Some companies even publish their own internal piping standards based upon national and industry sector standards.

Piping codes and standards from standardization organizations as **ANSI, ASME, ISO, DIN** and others, are the most common used in pipes and piping systems specifications.

The difference between piping codes and piping standards can be defined as:

Piping Codes :- Piping codes defines the requirements of design, fabrication, use of materials, tests and inspection of pipes and piping systems.

Piping Standards:- Piping standards define application design and construction rules and requirements for piping components as flanges, elbows, tees, valves etc.

Each country has its own codes & standards but American National Standards is most widely used & excepted all over world.
Following table lists some of the major organization for standards.

S/N	COUNTRY	ORGANIZATION	ABBREVIATION
1.	United States	American National Standard Institute.	ANSI
2.	Canada	Standard Council of Canada	SCC
3.	France	Association Francaise	AFNOR
4.	United Kingdom	British Standard Institute.	BSI
5.	Europe	Committee of European Normalization	CEN
6.	Germany	Deutsches institute fur Normung	DIN
7.	Japan	Japanese Industrial standards committee	JISC
8.	India	Bureau of Indian Standards	BIS
9.	Worldwide	International organization for standards	ISO

List of some American standards referred by Piping engineers.

- The American National standard Institute. (ANSI)
- The American Society for Testing & Materials. (ASTM)
- The American Society of Mechanical Engineers. (ASME)
- The American Petroleum Institute. (API)
- The American Iron & Steel Institute. (AISI)
- The American welding Society. (AWS)
- The Manufacturers Standardization Society of valves & fitting industry-standard practice. (MSS-SP)

List of some ASME standards.

ASME B 31.1	Power Piping
ASME B 31.2	Fuel gas piping
ASME B 31.3	Process Piping
ASME B 16.1	Cast iron pipe flanges & flanged fittings.
ASME B 16.3	Malleable iron threaded fittings
ASME B 16.4	Cast iron threaded fittings
ASME B 16.5	Steel Pipe flanges & flanged fittings.
ASME B 16.9	Steel butt welding fittings.
ASME B 16.10	Face to face & end to end dimensions of valves.
ASME B 16.11	Forged steel socket welding & threaded fittings.
ASME B 16.20	Metallic gaskets.
ASME B 16.21	Non Metallic gaskets.
ASME B 16.25	Butt welded ends.
ASME B 16.28	Short radius elbows & returns.
ASME B 36.10	Welded & seamless Wrought steel pipes.
ASME B 36.19	Welded & seamless stainless steel pipes.

List of some British standards.

BS 10	Flanges
BS 1414	Gate valve for petroleum industry.
BS 1560	Steel pipe flanges
BS 1640	Butt welding Fittings
BS 1868	Steel check valves for petroleum industry
BS 1873	Steel globe & check valves for petroleum industry
BS 1965	Butt welded pipe fittings.
BS 5151	Cast Iron gate valve
BS 5152	Cast Iron Globe & check valves
BS 5153	Cast Iron check valves
BS 5156	Diaphragm valves
BS 5158	Plug valves
BS 5153	Cast Iron check valves
BS 5351	Steel ball valve for petroleum industry.

PIPES & FITTINGS

PIPE:- pipes can be defined as a pressure tight cylinder used to transfer fluid.

SMALL BORE :- Pipes having size range ½" – 1 ½ " are termed as small bore.

BIG BORE :- Pipes having size range 2" & above are termed as big bore.

SINGLE RANDOM LENGTH :- Straight pipe in SRL is 6 meters.

DOUBLE RANDOM LENGTH :- Straight pipe in DRL is 11 meters.

COMMONLY USED PIPE SIZE

NPS	NB	OD
1/2	15	21.3
3/4	20	26.7
1	25	33.4
1 ½	40	48.3
2	50	60.3
3	80	88.9
4	100	114
6	150	168
8	200	219
10	250	273
12	300	324

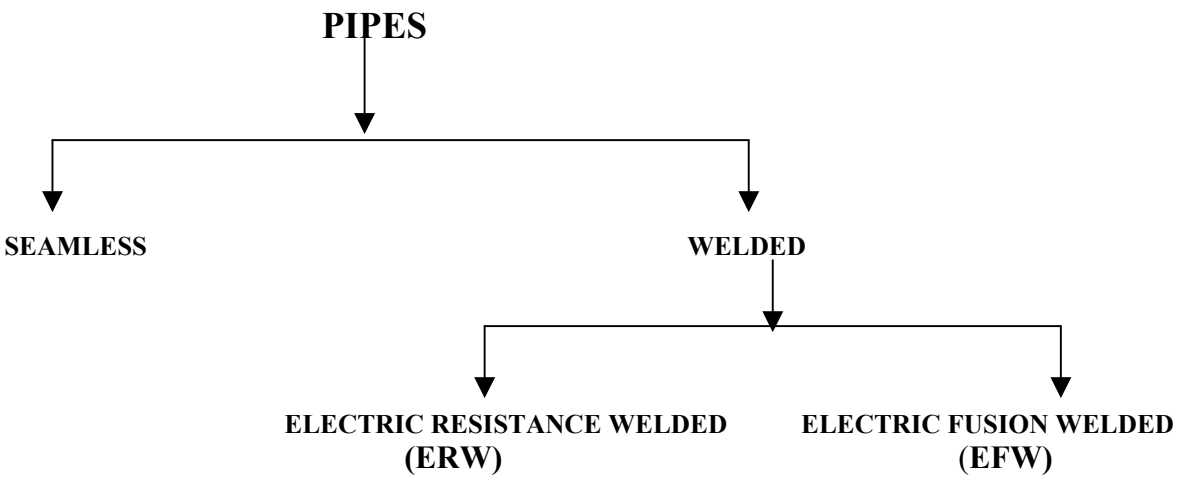
NOT COMMONLY USED PIPE SIZE:- 1 ¼ ", 2 ½ ", 3 ½ " & 5"

SCHEDULE:- The pipe thickness is designated by schedule no: and the corresponding thickness is specified in the ASME B 36.10 for carbon steel pipe & ASME B 36.19 for stainless steel pipes.
Stainless steel pipe are available in schedule **5S, 10S, 40S, 80S**
Carbon steel pipes are available in schedule **10,20,30,40,60,80,100,120,140,160,STD,XS,XXS**

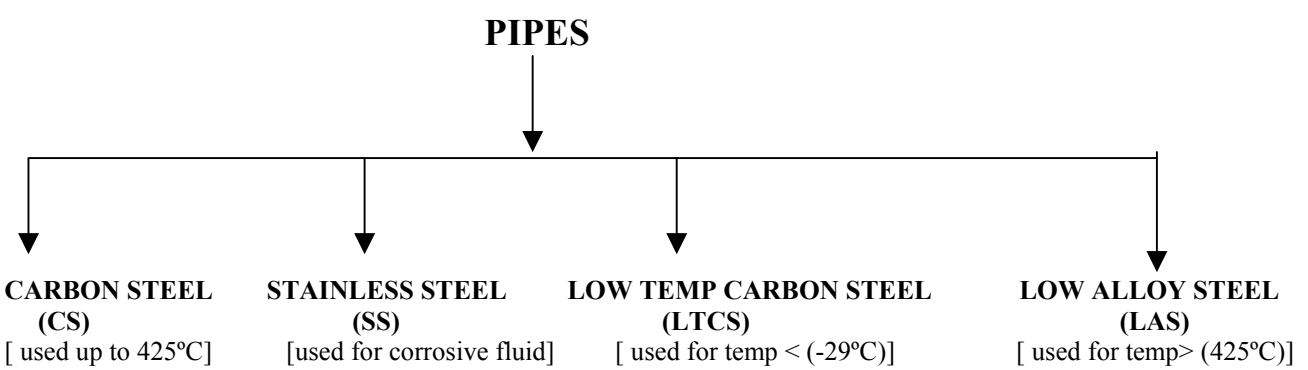
PIPE & TUBES

S/N	PIPES	TUBES
1	Pipes is specified by Nominal Bore (NB)	Tubes are specified by outside diameter
2	Wall thickness is expressed in schedule	Wall thickness is expressed in BWG (Birmingham wire gauge.)
3	Available in small bore as well as big bore.	Available in small bore only.
4	Used in all process & utilities line	Generally used in tracing lines, tubes for exchanger & in instrument connection.
5	The outside dia of pipe up to size 12" are numerically larger than corresponding size	Outside dia of tubes are numerically equal to the corresponding size.

CLASSIFICATION OF PIPES BASED ON METHOD OF MANUFACTURING



CLASSIFICATION OF PIPES BASED ON MATERIAL OF CONSTRUCTION



COMMENLY USED MATERIALS

PIPES & COMPONENT	MATERIALS			
	CARBON STEEL	STAINLESS STEEL	LOW ALLOY STEEL	LOW TEMP CARBON STEEL
PIPES	A53 Gr B (Welded/ SMLS) A106 Gr B (SMLS) API 5L Gr B (Welded/ SMLS) A672 Gr B60, (16" & above)	A312 Gr TP304 A312 Gr TP316 A312 Gr TP321 A358 Gr 304 A358 Gr 316 A358 Gr 321 A409 (14" & 30")	½ Cr-½Mo- A335 Gr P2 1Cr-½Mo- A335 Gr P12 1 1/4Cr-½Mo-A335 Gr P11 2 1/4Cr-1Mo-A335 Gr P22 3Cr-1Mo-A335 Gr P21 5Cr-1/2Mo-A335 Gr P5 9Cr-1Mo-A335 Gr P9 A691 Gr ……(EFW high T-T. 16" & above) (Add Cr % in blank space)	A333 Gr.6 (welded/SMLS) A671 Gr.CC60 (EFW,16" & Above)
FORGING (Flanges, 'o'let fittings, small bore valve ,fittings & special parts.)	A105	A182Gr.F304(18Cr -8Ni) A182Gr.F316(16Cr -12Ni-2Mo) A182Gr.F321(18Cr -10Ni-Ti)	½ Cr-½Mo- A182 Gr F2 1Cr-½Mo- A182 Gr F12 1 ¼ Cr-½Mo- A182 Gr F11 2 ¼ Cr-1Mo- A182 Gr F22 3 Cr-1Mo- A182 Gr F21 5 Cr-½Mo- A182 Gr F5 9Cr-1Mo- A182 Gr F9	A350 Gr.LF2 Class 1 & 2 .
WROUGHT FITTINGS	A333 Gr.6 (Welded/ SMLS)	A403Gr.WP304 A403Gr.WP316 A403Gr.WP321	1Cr-½Mo- A234 Gr.WP12 1 ¼ Cr-½Mo- A234 Gr.WP11 2 ¼ Cr-½Mo- A234 Gr.WP22 5 Cr-½Mo- A234 Gr.WP5 9 Cr-1Mo- A234 Gr.WP9	A420 Gr.WPL-6
CASTINGS (Large bore valve & special parts.)	A216 Gr.WCB	A351Gr.CF8 (SS 304) A351Gr.CF8M (SS 316) A351Gr.CF8C (SS 321)	1 ¼ Cr-½Mo- A217 Gr.WC6 2 ¼ Cr-1Mo- A217 Gr.WC9 5 Cr-½Mo- A217 Gr.C-5 9 Cr-1Mo- A217 Gr.C-12	A352 Gr.LCB
PLATES	A515 Gr.60	A240 Gr.304 A240 Gr.316 A240 Gr.321	½ Cr-½Mo- A387 Gr.2CL.1 1Cr-½Mo- A387 Gr.12CL.1 1 ¼ Cr-½Mo- A387 Gr.11CL.1 2 ¼ Cr-1Mo- A387 Gr.22CL.1 3 Cr-1Mo- A387 Gr.21CL.1 5 Cr-½Mo- A387 Gr.5CL.1½ 9Cr-1Mo- A387 Gr.9CL.1	A516 Gr.60
BOLTS/NUT	A193 Gr.B7 A194 Gr.2H (Bolt) A307 Gr.B A563 Gr.A (Nut)	A193 Gr.B8 Class II A194 Gr.8	A193 Gr.B16 A194 Gr.4	

Note:- Highlighted one are seldom used

THICKNESS CALCULATION AS PER ASME B 31.3:

The required thickness of straight sections of pipe as per ASME B 31.3 is given by

tm = t + c

where,

tm = Minimum required thickness including mechanical, corrosion and erosion allowances

t = Pressure thickness in order to sustain internal design pressure P

c = Sum of mechanical allowances (Thread or groove depth) plus corrosion and erosion allowances.

If 'T' is the Nominal pipe wall thickness then, T ≥ tm + Manufacturer's negative tolerance.
As per code,

$$T = \frac{PD}{2(SE+PY)}$$

where,

P = Internal design gauge pressure, psig
D = Outside diameter of pipe, inch
S = Allowable stress value for the pipe material, psi
E = Quality factor (Longitudinal weld joint efficiency for pipe)
Y = Coefficient as per Table - I, valid for t < D/6 and for materials shown. The value of Y (dimensionless factor varying with temperature) may be interpolated for intermediate temperatures.
d = Inside diameter of pipe.

TABLE - 1
Value of coefficient Y for t < D/6

	TEMPERATURE °F					
MATERIALS	900 & lower	950	1000	1050	1100	1150
Ferritic steels	0.4	0.5	0.7	0.7	0.7	0.7
Austenitic steels	0.4	0.4	0.4	0.4	0.5	0.7
Other ductile Materials	0.4	0.4	0.4	0.4	0.4	0.4
Cast Iron	0.0	-	-	-	-	-

GENERAL NOTES :

- **'S' Allowable Stress Values:**

Allowable stress values for different ASTM pipe materials at various temperatures are listed under Table A1 ASME B 31.3 (Appendix A)

e.g. Allowable stress for:
A53Gr.B at 200 °F = 20,000 psi
A53Gr.B at 500 °F = 18,900 psi
A106Gr.B at 600 °F = 17,300 psi

- **'E' weld joint efficiency (Quality factor):**

Weld joint efficiency (Quality factors) for different ASTM pipe material specifications are listed under Table A1B ASME B 31.3

e.g. Quality factors for:

A53 ERW = 0.85
A53 Seamless = 1.00
A312 Seamless pipe = 1.00
A312 EFW double butt seam = 0.85
A312 EFW single butt seam = 0.80
(For all seamless pipes 'E' value is 1.00)

- **'C' Sum of Mechanical, corrosion and erosion allowances.**

Following are the usual allowances to be accounted.

1. Threads:

This is applicable if the pipes are threaded for making joints as is the case with galvanized piping. The nominal thread depth has to be accounted under such situation.

2. Corrosion/erosion allowances:

These allowance depend upon the type of fluid handled and are indicated by the Process licenser. These allowances vary from 1mm to 6mm, and in some cases even more. As a good engineering practice, it is advisable to consider minimum 1mm corrosion allowance for all other services where Process licenser has not specifically indicated any requirement. This also takes care of external corrosion if any.

3. Bending Allowance:

If the pipes are to be used for making bends, then it may be necessary to increase the thickness 'tm' by a factor called bend-thinning allowance. During bending the outer fibres get stretched and in order to maintain minimum wall thickness 'tm' at all point in a completed bend, one has to add allowance for thinning.

Flattening of a bend, the difference between maximum and minimum diameters at any cross section, shall not exceed 8% of nominal outside diameter for internal pressure.

Radius of Pipe Bend	Min. THK. recommended prior to bending
6D (nom. Dia)	1.06 t_m
5D	1.08 t_m
4D	1.14 t_m
3D	1.25 t_m

- **Manufacturer's Negative Tolerance:**

While specifying the pipe thickness for ordering, it is necessary to account for Manufacturer's negative tolerance since we require minimum thickness 'tm' at all points after the pipes are manufactured.

The tolerances depend upon the method of manufacturing pipes and these are given in respective ASTM PIPE material specs. The negative tolerance on specified thickness is 12 1/2 % for seamless pipes.

Thus for seamless pipes if 'tm' is the minimum thickness required then the nominal thickness T should be equal or greater than tm / 0.875.

Similarly, for electric fusion welded steel pipes as per ASTM A672 the manufacturer's negative tolerance is 0.01 inch (0.3mm). Hence for pipes conforming to A 672 nominal thickness T should be equal or greater than (tm + 0.01 inch)

- **Schedule-Number Selection**

After calculating 'T' the nominal wall thickness which is required for design conditions, one can order the pipes provided the quantity is large enough for special rolling. Otherwise, as per ANSI B36.10 for Carbon steel and ANSI B36.19 for stainless steel, Pipes are readily available in various thickness specified by their schedule numbers

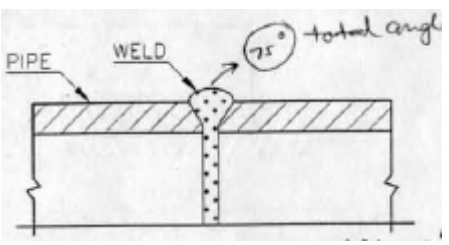
It is recommended to make use of these standard pipe thicknesses, which are available. Schedule number selected should have nominal thickness equal or greater than the calculated nominal thickness required for design condition.

PIPE ENDS

- Beveled ends.
- Plain ends.
- Screwed ends.
- Flanged ends.
- Socket ends.

METHOD OF JOINING PIPES.

i. BUTT WELDED:-



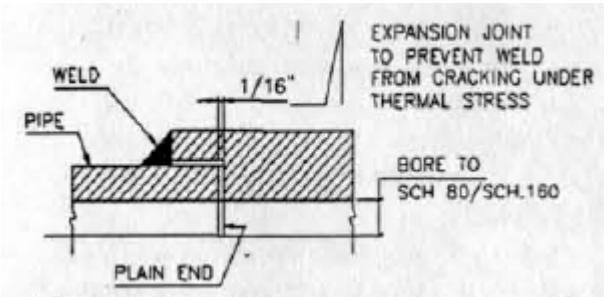
ADVANTAGES

- Most economical method of joining big bore lines.
- Joint is leak proof.
- Joint can be radio graphed.

DISADVANTAGES

- Weld intrusion will affect the flow.
- End preparation is necessary.

ii. SOCKET WELDED:-



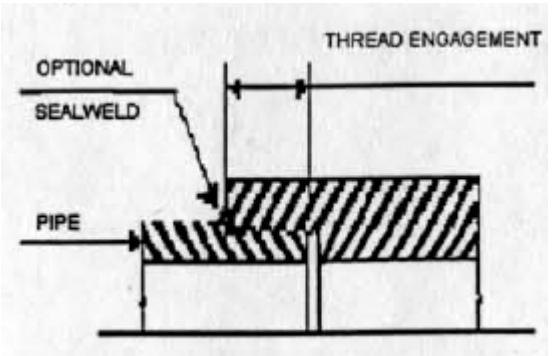
ADVANTAGES

- Alignment is easier than butt welded.
- No intrusion of weld metal inside the pipe.
- Leak proof joint.
- Generally used to connect small bore lines.

DISADVANTAGES

- The 1 1/16 recess pocket .
- Not suitable when service fluid is corrosive in nature.
- Not suitable when vibration is anticipated.

iii. **SCREWED:-**



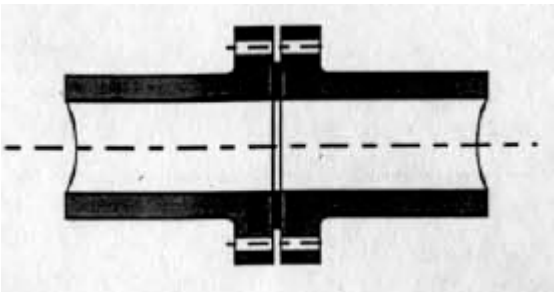
ADVANTAGES

- Easy to made it at site.
- Can be used where welding is prohibited due to fire hazard.
- Generally used to connect small bore lines.

DISADVANTAGES

- Leak proof joint cannot be guaranteed. .
- Not suitable when service fluid is corrosive in nature.
- Not suitable when vibration is anticipated.
- Not suitable when operating temperature is above 925 F.
- Thread reduces the wall thickness, consequently reducing the strength.

iv. **FLANGED:-**



ADVANTAGES

- Easy to made it at site.
- Can be used where welding is prohibited due to fire hazard.
- Dismantling is very easy.

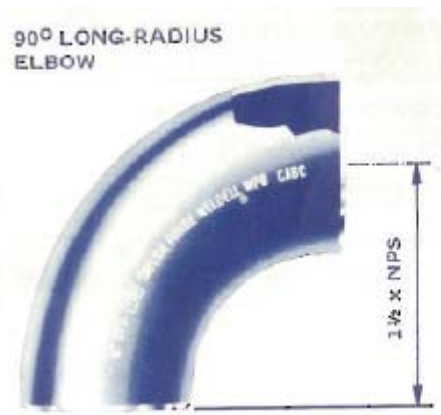
DISADVANTAGES

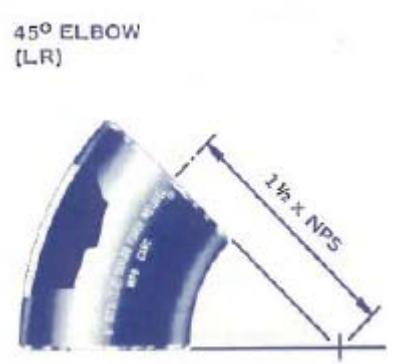
- Leak proof joint cannot be guaranteed. .
- Its an expensive method of joining pipes..
- Not suitable when high bending moment is anticipated.

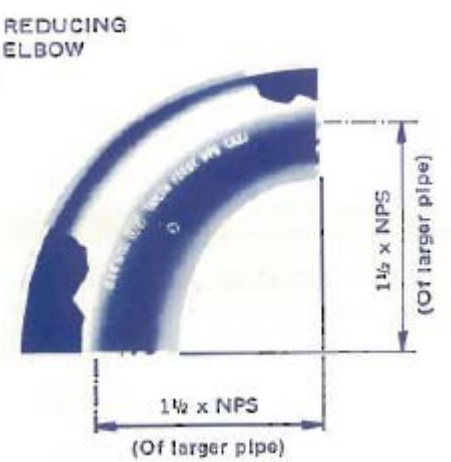
ELBOWS:- Based on end connection elbows are of following types.

- **Butt-welded elbow.**
- **Socket elbow.**
- **Threaded elbow.**

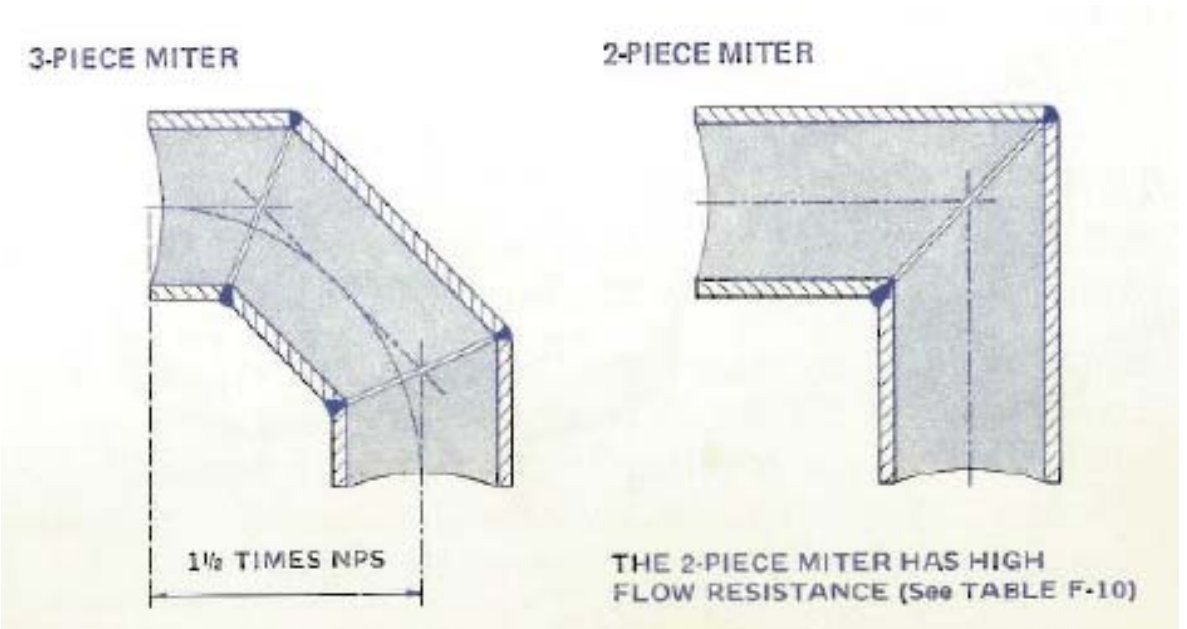
- **Available in 90º& 45º elbows.**
- **Available in short radius & Long radius pattern.**
- **Available as reducing elbow.**

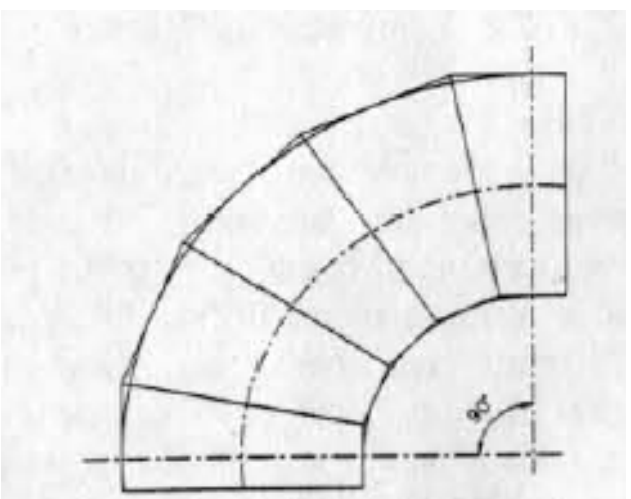




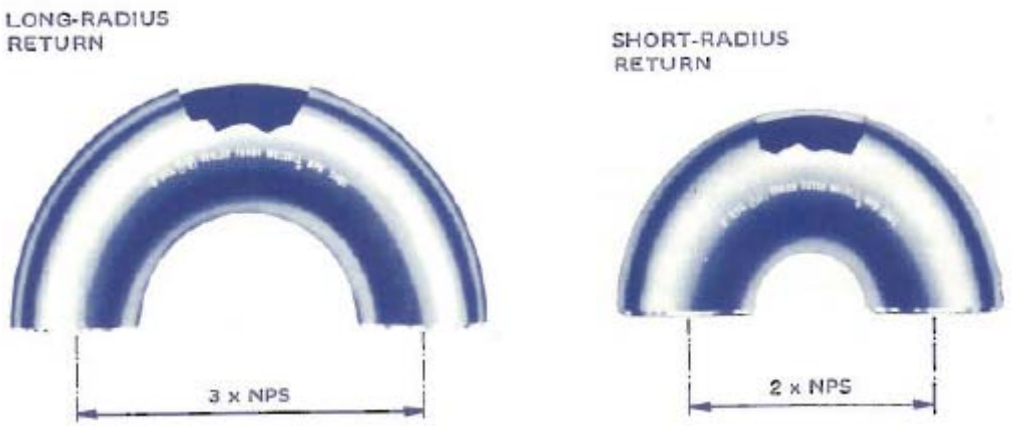


MITER BEND:- Miter bends are not standard fittings they are fabricated from pipes. Usually they are preferred for size 10” & above because large size elbow is expensive & not easily available in the market. Use of miter bend is restricted to low pressure.. Miter bend can be fabricated in 2 , 3 , & 5 piece.



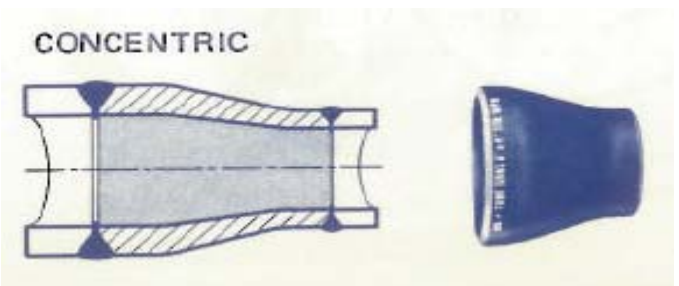


RETURNS:- Reducing elbows are used to make 180º change in direction. Available in short & long pattern. Mainly used in heating coil, heat exchanger etc.

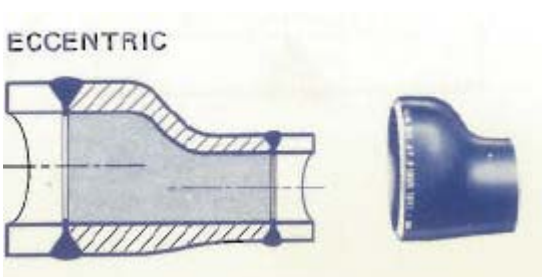


REDUCER:- Reducers are used to connect larger dia pipe to smaller dia pipes & vice versa. There are two types of reducers

- ***CONCENTRIC REDUCERS:- It maintains the center line elevation of pipe line.***

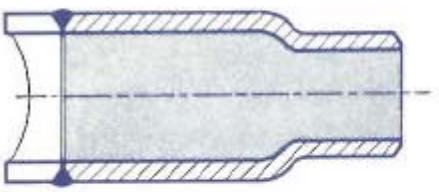


- ***ECCENTRIC REDUCERS:- It maintains BOP (bottom of pipe) elevation of pipe line.Offset is equal to ½ X (larger ID minus smaller ID).***

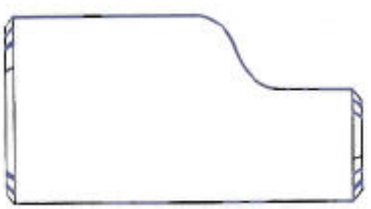


SWAGE:- Swage is like reducers used to connect butt welded pipes to smaller screwed or socket welded pipes. Like reducers they are concentric & eccentric type. they are covered under the regulatory code BS – 3799.

CONCENTRIC



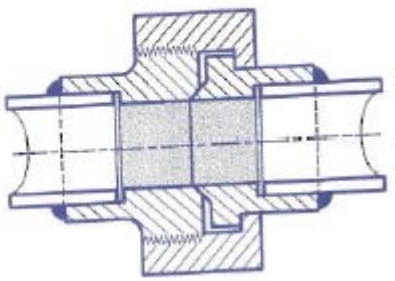
ECCENTRIC



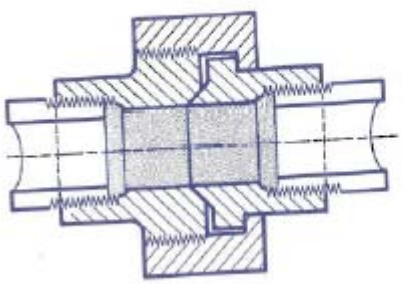
VENTURI TYPE

UNION:- Union is used to connect small bore pipes. It can be socket end or threaded end

SOCKET-WELDING UNION

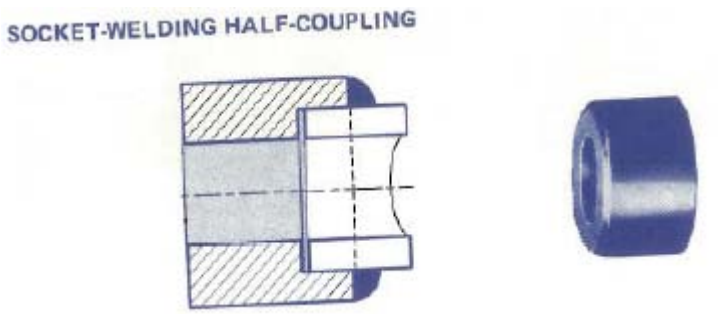


SCR EWED UNION

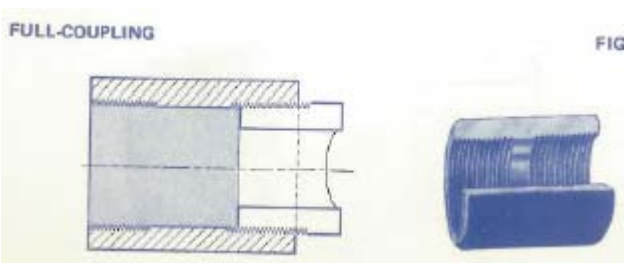


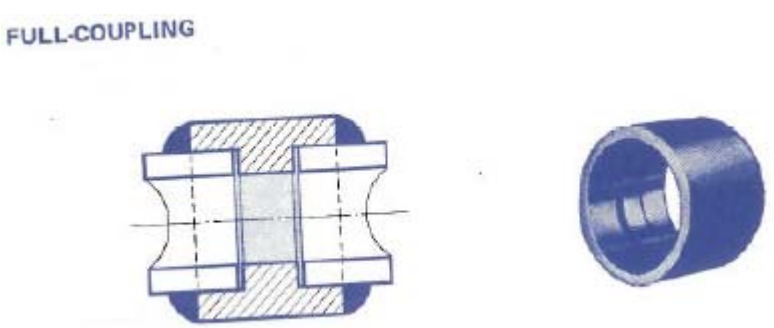
(COURTESY STANLEY G. FLAGG & CO. INC)

HALF COUPLING:- Generally used for branching or for vessel connections. It can be threaded or socket type.



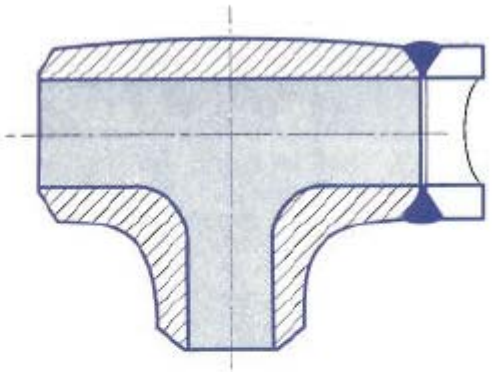
FULL COUPLING:- Generally used for connecting pipes or items with either threaded or socket ends.





TEES :- Tees are used for making 90º branch from main run of pipe .Branch size may be of same size or less than the main header size.

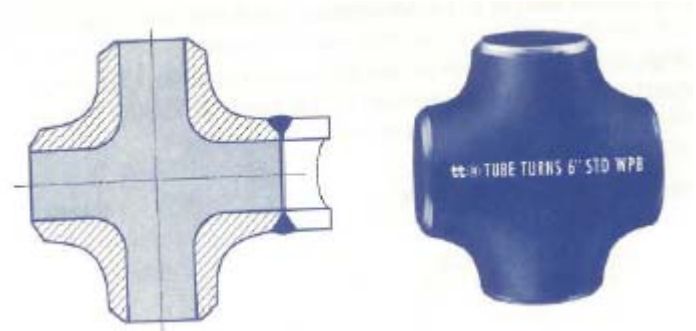
BUTT-WELDING TEES FIGURE



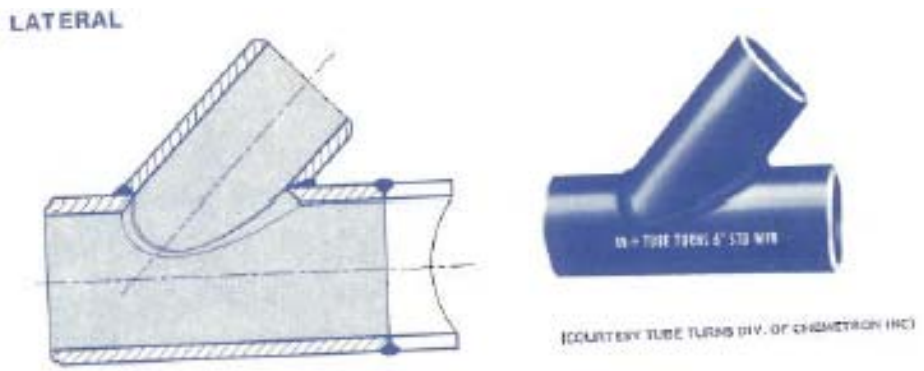
STRAIGHT BUTT-WELDING TEE

REDUCING BUTT-WELDING TEE

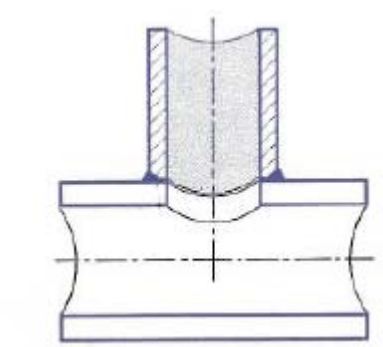
CROSS :- Straight cross are usually stock items. Reducing cross may not be readily available hence it is proffered to use TEE instead of reducing Cross-except where space is restricted.



LATERALS: - It permits entry of branch to a main header at 45º angles. It is used where low resistance to flow is required especially in flare lines. Branch size may be of equal size or reducing. Branch angle other than 45º angles is possible only to special order.



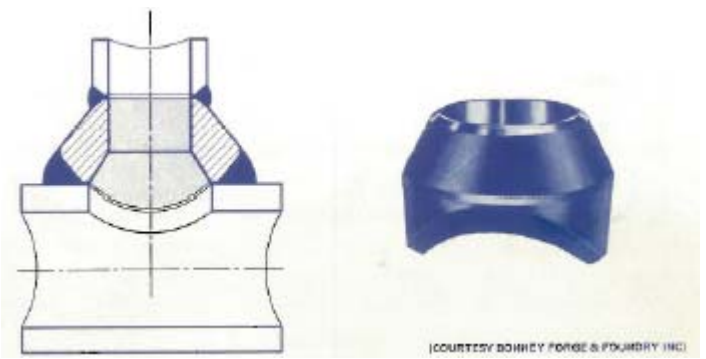
STUB-IN :- Stub –in is not any standard fittings .This term is used for branch pipe directly welded to main pipe run. If required it may be re-inforced. This is the most common & least expensive method to branch full size or reducing size from main header,



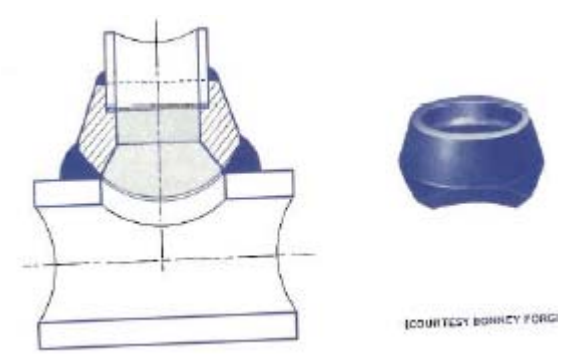
'O' LET FITTINGS: - These are the special fittings available readymade in the market. It does not require any reinforcement. They are preshaped to the curvature of the run pipe & end preparation is pre done.

The items listed in 'O' let fittings are

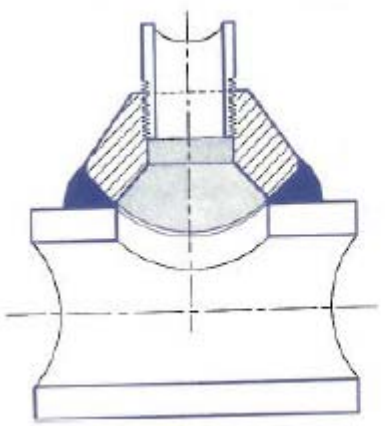
- ***WELDOLET***



- ***SOCKOLET***

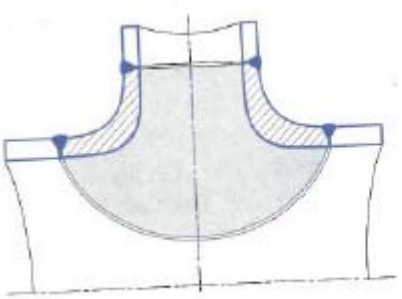


- ***Threadolet***



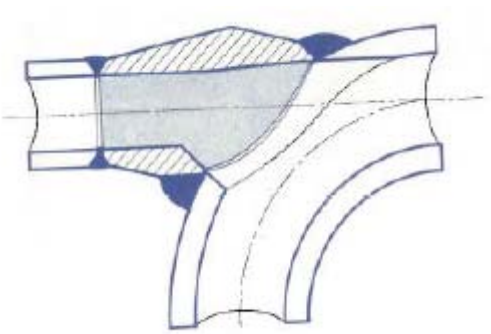
(COURTESY BONNEY FORGE & FOUNDRY I

- ***SWEEPOLET***

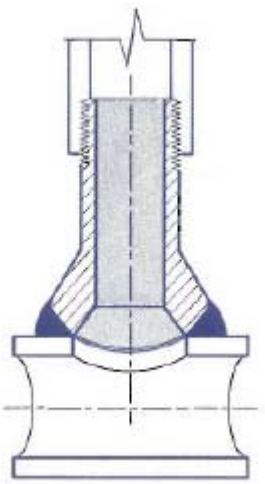


(COURTESY BONNEY FORGE & FOUNDRY

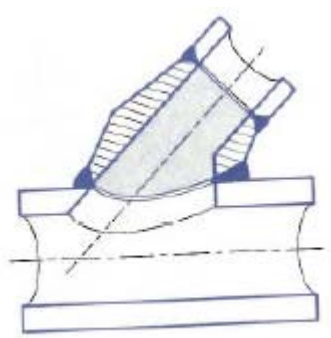
- ***ELBOWLET***



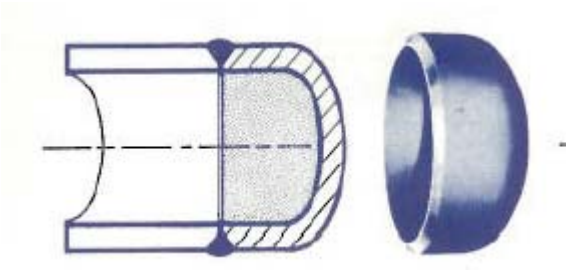
- ***NIPOLET***



- ***LATEROLET***



CAP :- Cap is used to seal end of pipe.



FLANGES.

Flanges are used to connect

- Pipe to pipe, which require frequent dismantling.
- Pipe to equipment.
- Pipe to valves.
- Pipe to special items.

A flanged joints consist of three integral parts namely **flanges, gasket, Bolt & Nut.**
The design standard for Flanges is ASME B 16.5.

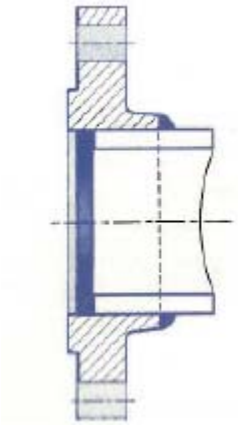
Based on P-T ratings flanges are classified as

150#
300#
400#
600#
900#
1500#
2500#

Based on attachment flanges are classified as

i. Slip-on
ii. Socket weld.
iii. Screwed.
iv. Weld Neck
v. Reducing
vi. Lap joint.
vii. Blind.

SLIP-ON FLANGE



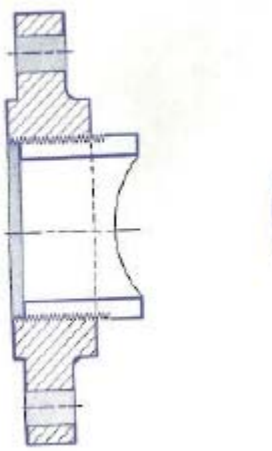
- Flange is attached by welding inside as well as outside.
- Pipe is set back 1/16 “from the face of flange.
- Internal weld is subjected to corrosion, hence not preferred for corrosive service.
- Poor resistant to shock & vibration.
- Cheaper to buy but costlier to assemble.
- Easier to align.
- The strength is about 1/3 that of the corresponding weld neck flange.

SOCKET WELD FLANGE

- Welded only on one side, hence not recommended for severe service.
- Used only for small bore pipes
- Not recommended for service above 250ºC & below -45ºC

SCREWED FLANGES

- Used to connect screwed pipe to flanged items.
- Used only for small bore pipes
- Not recommended for service above 250ºC & below -45ºC
- Used where welding cannot be used for hazardous reasons.



(COURTESY TAYLOR FORGE INC)

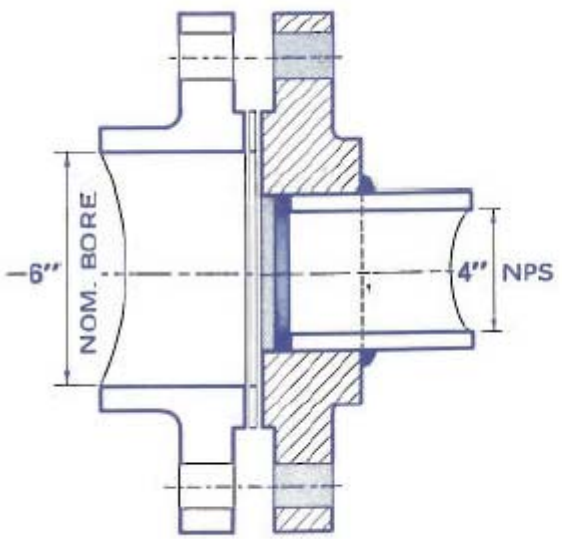
WELD NECK FLANGE

- Flanges are attached by butt-welding to pipes.
- Suitable where extreme temperature, shear, impact & vibratory stress apply.
- Welding can be radiigraphed.
- Costly.

(COURTESY TAYLOR FORGE INC)

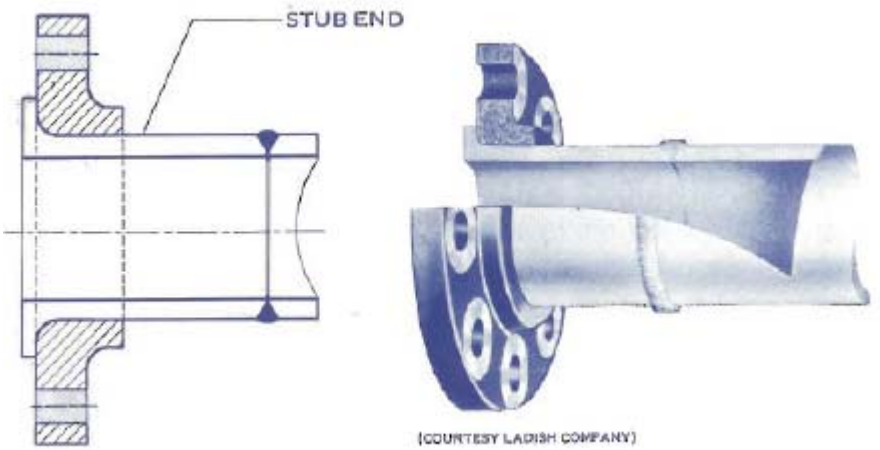
REDUCING FLANGE

- Used to connect bigger pipe to smaller pipes.
- Available in slip-on or weld neck type.
- Should not be used if abrupt transition would create undesirable turbulence.
- Specified by the line size of smaller pipe & OD of the flange to be mated.



LAP JOINT FLANGE

- It is used to connect pipe of costlier material like stainless steel.
- This is used along with stub-end. Material of stub-end will be as pipe & flange will be of cheaper material like carbon steel.
- Stub-end will be butt welded to the pipe & flange is kept loose over it.
- It is also useful where alignment of bolt is difficult.

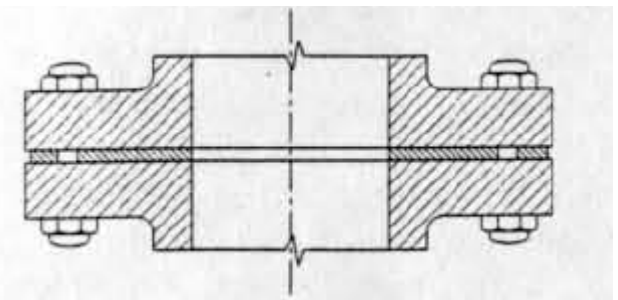


BLIND FLANGE

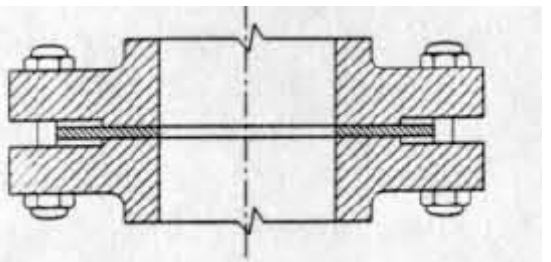
- Generally used to close the pipe end, which need to be reopened later.

Based on Facing flanges are classified as

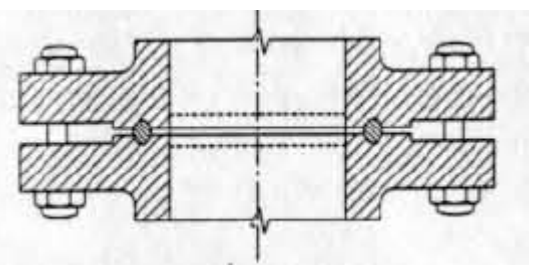
i. Flat face. (FF)
ii. Raised face. (RF)
iii. Ring Type Joint. (RTJ)
iv. Tongue & groove Joints.
v. Male/female Joints.



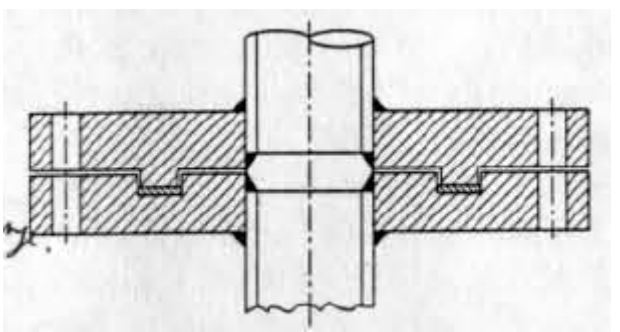
FLAT FACE



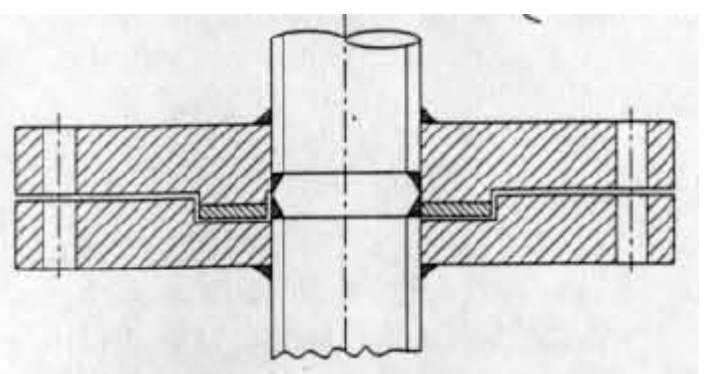
RAISED FACE



RING JOINT



TONGUE & GROOVE JOINT



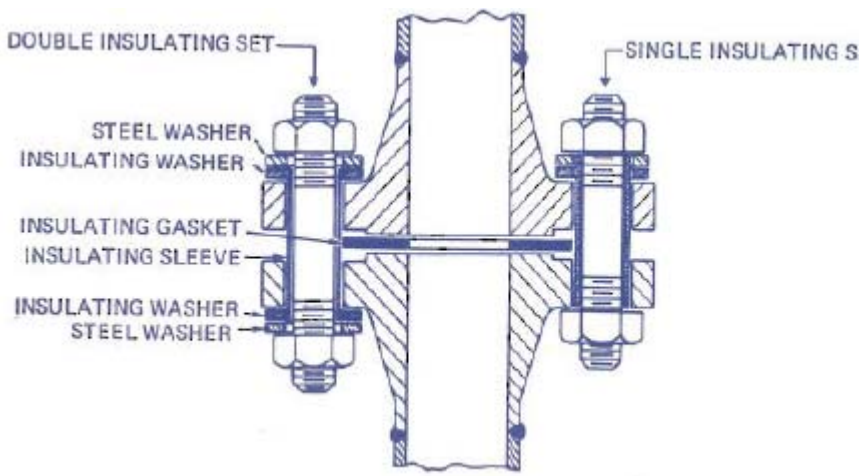
MALE / FEMALE JOINT

GASKET.

Gaskets are used to provide fluid resistant seal between the flanges. It can be metallic or non-metallic type metallic gasket is referred to ASME B 16.20 & non –metallic gasket is referred to 16.21.
Metallic gasket is further categorized as Spiral wound, corrugated metallic & ring type joint.

Selection of Gasket depends on following factor.

- P-T of the fluid service.
- Corrosive nature of the fluid service.
- Code requirement.
- Cost



GASKET MATERIAL	EXAMPLE USE	MAXIMUM TEMPERATURE (Deg F)	MAXIMUM 'TP' FACTOR Temperature x Pressure (Deg F x PSI)	AVAILABLE THICKNESS (INCHES)
Synthetic rubbers	Water, Air	250	15,000	1/32,1/16,3/32,1/8,1/4
Vegetable fiber	Oil	250	40,000	1/64,1/32,1/16,3/32,1/8
Synthetic rubbers with cloth insert ('CI')	Water, Air	250	125,000	1/32,1/16,3/32,1/8,1/4
Solid Teflon	Chemicals	500	150,000	1/32,1/16,3/32,1/8
Compressed asbestos	Most	750	250,000	1/64,1/32,1/16,1/8
Carbon steel	High-pressure fluids	750	1,600,000	For ring-joint gaskets, refer to table R-1, part II
Stainless steel	High-pressure &/or corrosive fluids	1200	3,000,000	
Spiral-wound: SS/Teflon CS/Asbestos SS/Asbestos SS/Ceramic	Chemicals Most Corrosive Hot gases	500 750 1200 1900	250,000+	Most-used thickness for spiral-wound gaskets is 0.175. Alternative gasket thickness: 0.125.

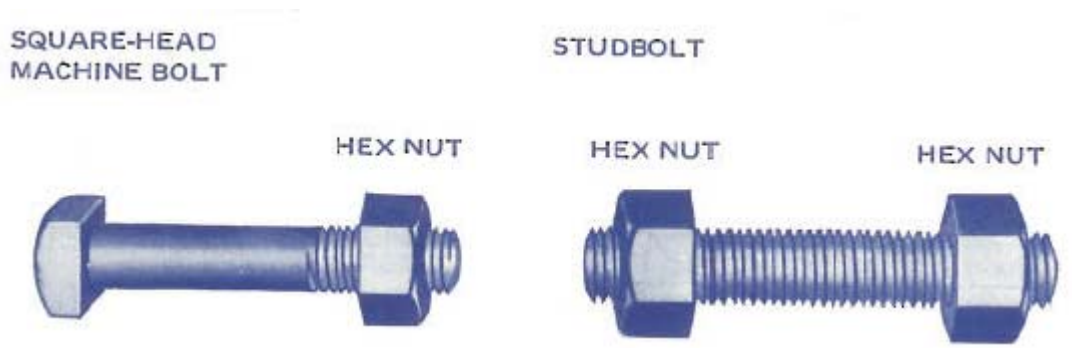
BOLTS & NUTS.

Two types of bolt are generally used in the industry

- Machine bolt
- Stud bolt

Design standard for bolt & nut is ASME B 16.5

- For low P-T machine bolt is preferred otherwise studs
- Bolts are provided with hexagonal head, hexagonal nuts & washer.



VALVES

CLASSFIICATION

Valves are classified according to their action performed.

- ✓ Isolation
- ✓ Regulation.
- ✓ Checking
- ✓ Switching
- ✓ Discharging

ISOLATION VALVES.

- Gate valve
- Ball valve
- Plug valve
- Piston valve
- Diaphragm valve.
- Butterfly valve.

……..

REGULATION VALVES.

- Globe valve.
- Needle valve.
- Butterfly valve.
- Diaphragm valve.
- Piston valves.

CHECKING VALVES.

- Check valve.
- Foot valve.

SWITCHING VALVES.

- Multiport valve.
- Diverting valve.

DISCHARGING VALVES.

- Safety valve.
- Relief valve.
- Safety relief valve.
- Flush bottom valve.
- Rupture disc.

MAIN PARTS OF VALVES.

Disc:- The moving part that directly effect the flow is called as disc.

Seat:- The non-moving part on which the disc bears is called as seat.

Port:- The maximum internal opening of the valve in fully open position.

Stem:- There are two types of screwed stem. The rising & non rising stem.

The rising stem can either be inside screw or outside screw .The outside screw type has a yoke on bonnet & referred to as 'outside screw & yoke' (OS&Y). the hand wheel can either rise with the stem or stem can rise through the hand wheel.

In Non- rising stem hand wheel & stem are in the same position whether the valve is open or closed. The screw is inside the bonnet.

Bonnet :-The bonnet is connected to the body . The type of connection can be flanged bolted, bellow sealed, screwed –on, welded, union, pressure sealed etc.

Body :-The valves are connected to pipe, fittings or vessel by their body ends, which may be flanged, screwed, butt or socket welding.

TERMS USED FOR VALVE SPECIFICATION.

P-T ratings :- The maximum allowable sustained non-shock pressure at the corresponding tabulated temperature. These are listed in ANSI B 16.34 & ANSI B 16.5.

Class:- The valve is specified by the pressure rating of the body of the valves. The American standard specifies the following class.
Class 150 #
Class 300 #
Class 400 #
Class 600 #
Class 900 #
Class 1500 #
Class 2500#
Class 800#
Class 4500#

Trim:- The trim mainly comprises of stem, seat surface, bushing & other internal parts, which are in contact with the fluid.

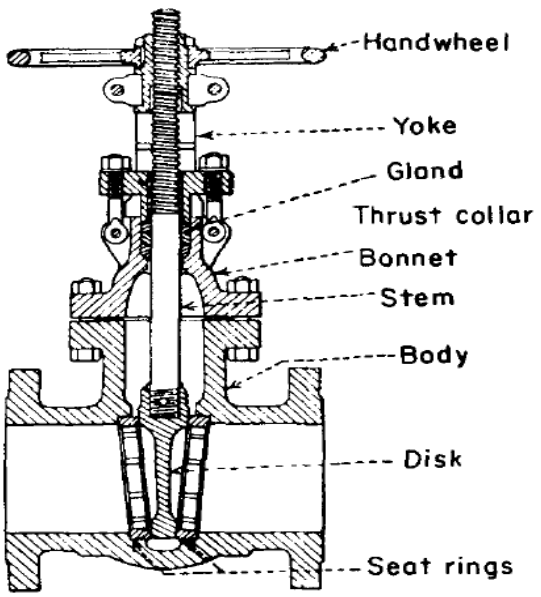
API 600 specifies trim No: & the material that can be used for parts with its typical specification & grade.

Trim No.	Nominal Trim	Seat hardness (HB[a], minimum)	Material Type	Typical Specification (Grade) Cast	Forged	Welded
1	F6	b	13 Cr	ASTM A217 (CA15)	ASTM A182 (F6a)	AWS A5.9 ER410
2	304	c	18-8 Cr-Ni	ASTM A351 (CF8)	ASTM A182 (F304)	AWS A5.9 ER308
3	F310	c	25-20 Cr-Ni		ASTM A182 (F310)	AWS A5.9 ER310
4	Hard F6	750[d]	Hard 13 Cr			
5	Hardfaced	350[d]	Co Cr-A[h]			AWS A5.13 ERCoCr-A
5A	Hardfaced	350[d]	Ni-Cr			
6	F6 and Cu-Ni	250[f] 175[d]	13 Cr Cu-Ni	ASTM A217 (CA15)	ASTM A182 (F6a)	AWS A5.9 ER410
7	F6 and Hard F6	300[f] 750[f]	13 Cr Hard 13 Cr	ASTM A217 (CA15)	ASTM A182 (F6a)	AWS A5.9 ER410
8	F6 and Hardfaced	300[f] 350[f]	13 Cr Co Cr-A[h]	ASTM A217 (CA15)	ASTM A182 (F6a)	AWS A5.9 ER410 AWS A5.13 ER CoCr-A
8A	F6 and Hardfaced	300[f] 350[f]	13 Cr Ni-Cr	ASTM A217 (CA15)	ASTM A182 (F6a)	AWS A5.9 ER410
9	Monel	c	Ni-Cu alloy	—	Manufacturer's standard	—
10	316	c	18-8 Cr-Ni	ASTM A351 (CF8M)	ASTM A182 (F316)	AWS A5.9 ER316
11	Monel	c	Ni-Cu alloy	—	—	—
	Hardfaced	350[f]	Trim 5 or 5A	—	Manufacturer's standard	See Trim 5 or 5A
12	316 and Hardfaced	c 350[f]	18-8 Cr-Ni Trim 5 or 5A	ASTM A351 (CF8M)	----- ASTM A182 (F316)	AWS A5.9 ER316 See Trim 5 or 5A
13	Alloy 20	e	19-29 Cr-Ni	ASTM A351 (CN7M)	-----	AWS A5.9 ER320
14	Alloy 20 and Hardfaced	c 350[f]	19-29 Cr-Ni Trim 5 or 5A	ASTM A351 (CN7M) —	ASTM B473 ASTM B473 -----	AWS A5.9 ER320 See Trim 5 or 5A

a HB is Brinell hardness number symbol per ASTM E10 (formerly BHN).
b Body and gate seats 250 HB minimum, with 50 HB minimum differential between body and gate seats.
c Manufacturer's standards hardness
d Differential hardness between body and gate seat surfaces not required.
e case hardened by nitriding to thickness of 0.005- inch (0.13 millimeters) minimum.
f Hardness differential between body gate seats shall be as per the manufacturer's standard.
g Manufacturer's standard, within 30 Ni minimum
h This classification includes such trademarked materials such as stellite 6, Stoody 6, and Wallex 6.
i Manufacturer's standard hardfacing, with 25 percent Fe maximum.

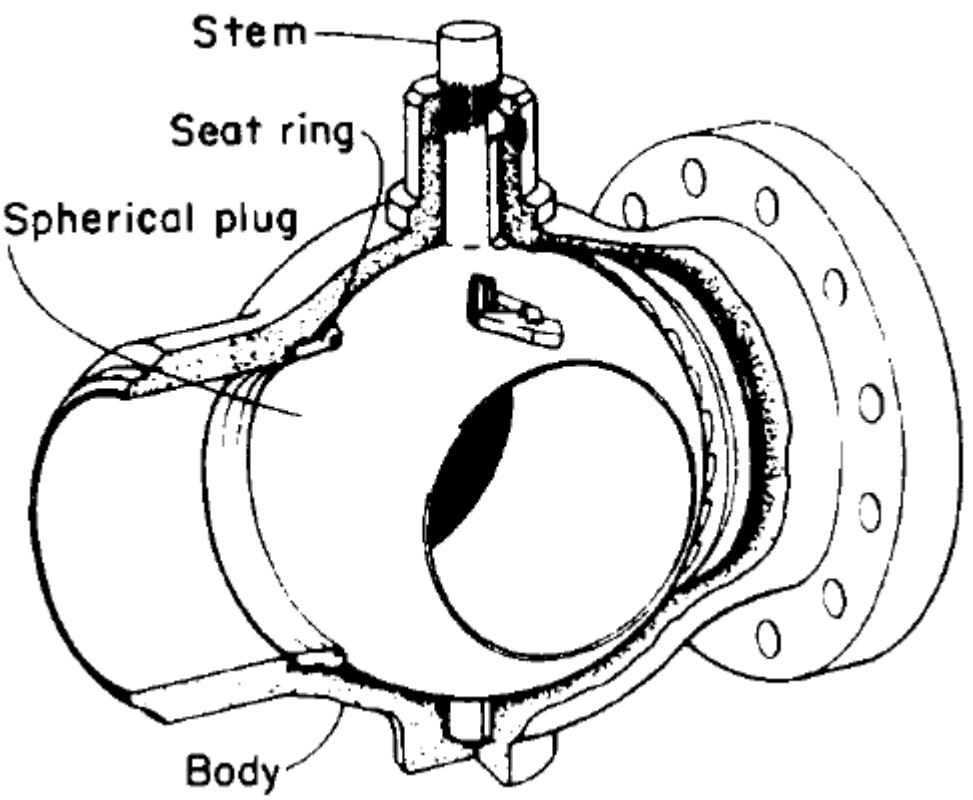
GATE VALVE.

- It is an isolation valve, can't be used for regulation.
- Designed to operate fully open or fully closed.
- Fluid hammer is minimum as it operates slowly.
- Pressure drop through gate valve is less.
- In fully closed position gate valve provide positive seal under high pressure.
- Under low pressure there can be seepage of 5psi.which is not considered abnormal.
- Size range ½" – 12"



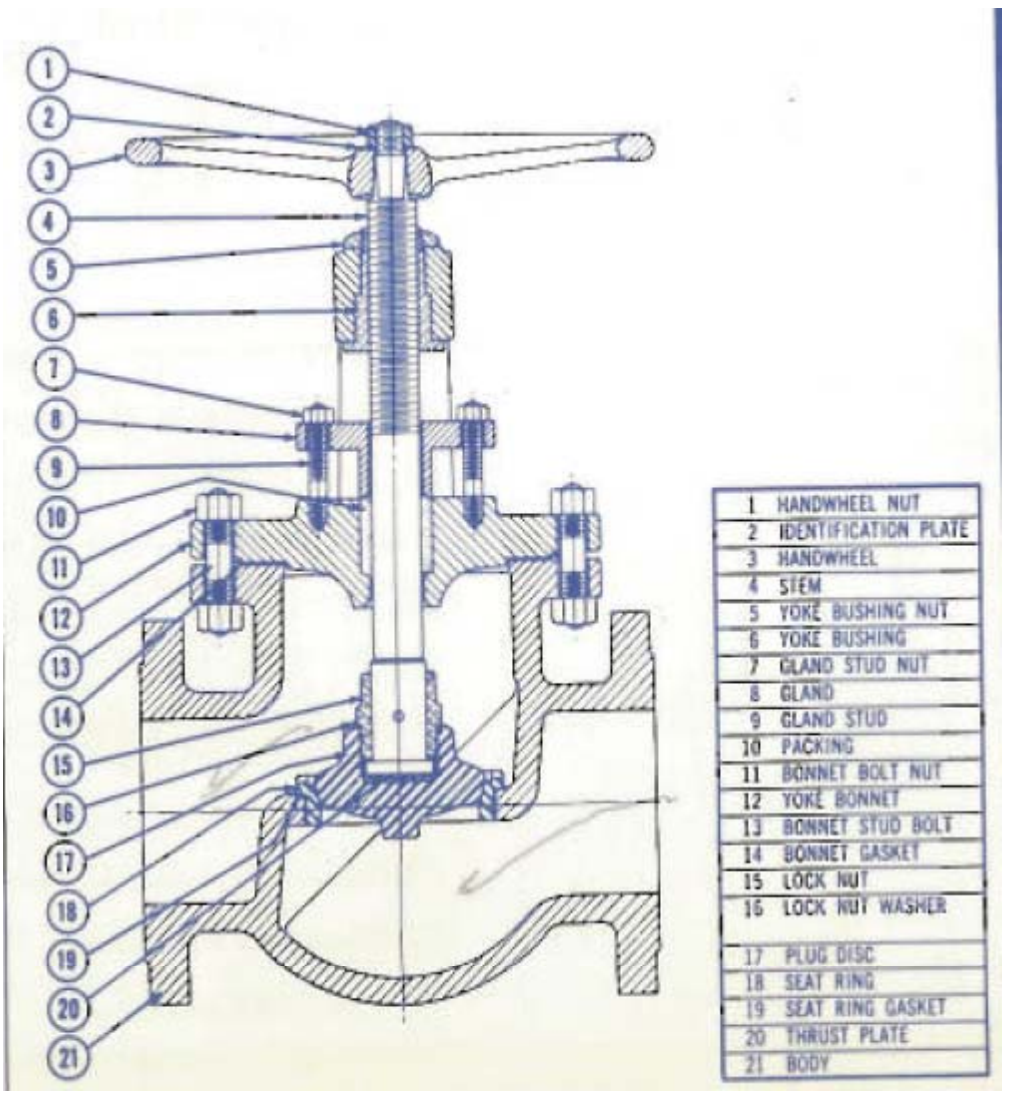
BALL VALVE.

- Ball valve is an isolation valve but in some case it can be used as a regulation valve.
- It is designed to operate fully open or fully closed.
- Ball valve is quarter turn valve hence it can be quickly opened or closed.
- It is suitable for gas, compressed air & slurry services.
- Quick opening / closing causes fluid hammering.
- Pressure drop is less.



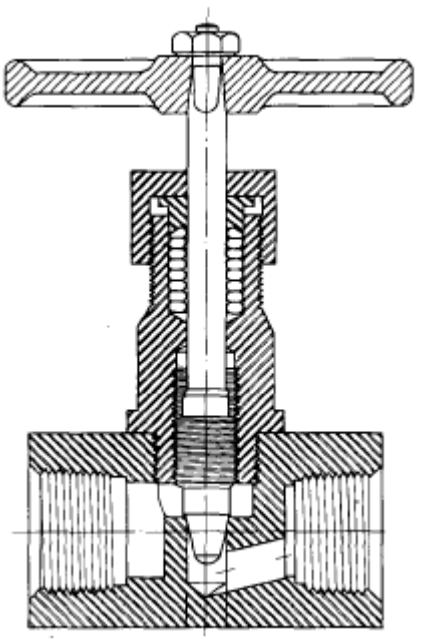
GLOBE VALVE.

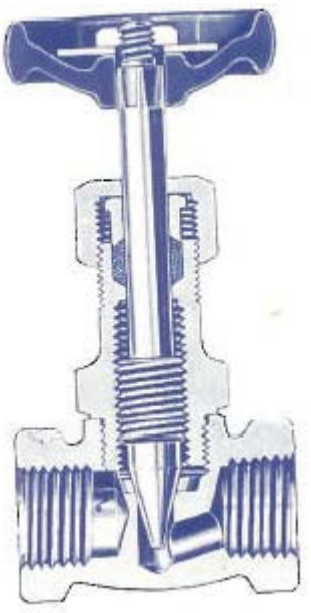
- Globe valve is a regulation valve.
- It open & closes slowly so fluid hammer is minimum.
- There is leakage under low pressure in fully close position.
- Pressure drop is comparatively higher gate, ball.
- Main disadvantage is the 'Z' pattern design which restrict the flow more then gate, ball or butterfly valve.
- Size range is ½" – 12"



NEEDLE VALVE.

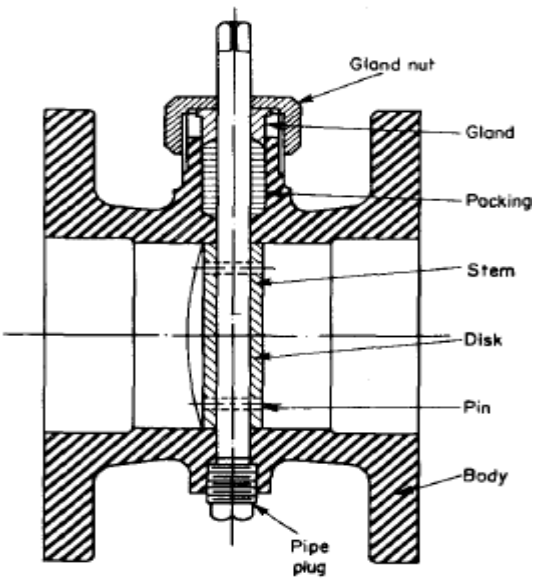
- It is a type of globe valve. Only the wedge in the shape of needle.
- Used for the precise flow of fluid.
- Generally used for instrument, gauge & meter line service.





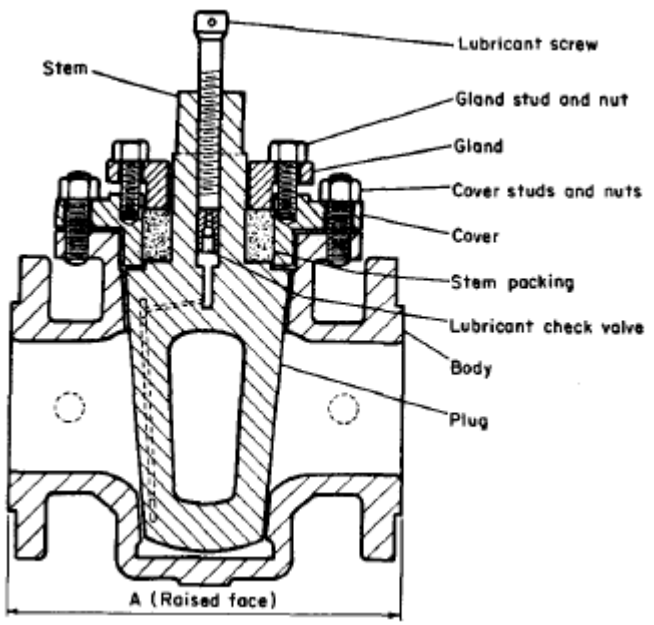
BUTTERFLY VALVE.

- It is an isolation valve.
- It can be used for regulation but not for extended period.
- Advantage is the low weight, compact design hence preferred over gate valve in large bore.
- Like ball valve it operates with a $1/4^{th}$ turn.
- It is designed for handling large flow of gases or fluid including slurries.
- Size range 2”- 12”



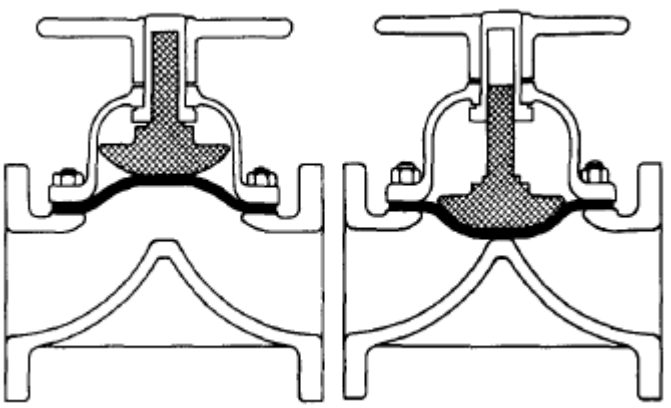
PLUG VALVE.

- Plug valve is an isolation valve.
- Like ball valve it require only 90º turns to open it.
- Valve design is very compact.
- It requires little headroom.
- Steam corrosion is minimum as there is no screw thread.
- Suitable for highly viscous fluid.
- Available in much higher size then the ball valve



DIAPHRAGM VALVE.

- Mainly an isolation valve but cat can be used for regulation also.
- Mainly used for low pressure corrosive fluid or where high degree of purity is requires e.g.. Pharmaceutical & food processing industries.
- Diaphragm moves ups & down to operate the valve.
- Body & bonnet is made of casting. Body is lined with corrosive resistant materials. Diaphragm is generally made of rubber or PTFE.
- There is no API or ANSI standard available for this valve. these are covered by British standards & MSS-SP standards.



Open position **Close position**

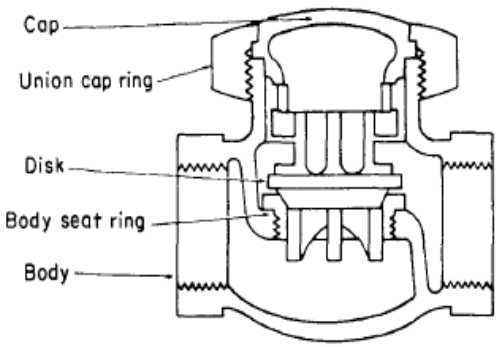
CHECK VALVE.

- Check valves are directional control valve, which prevent the back flow in lines.
- The common types of check valves used are lift type, swing type & wafer type.

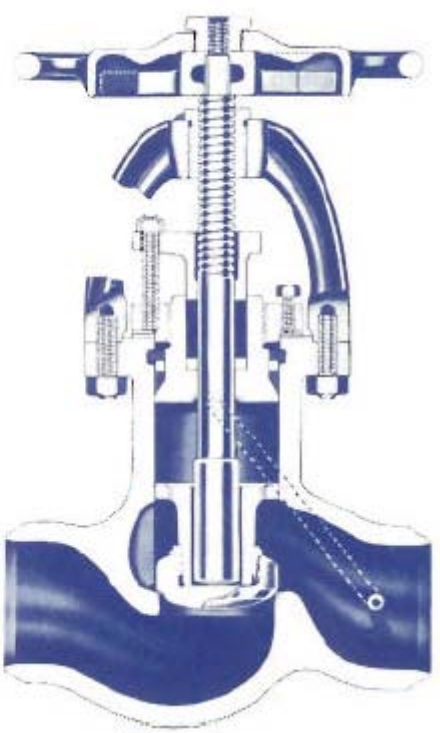
➢ ***LIFT CHECK VALVE***

These are operated by lifting action of the disk / elements. The different type of lift check valve available are

i. Piston lift check :- It can be placed in horizontal pipe line only.
ii. Ball lift check :- It comes in both horizontal & vertical pattern hence can be used in both the position.

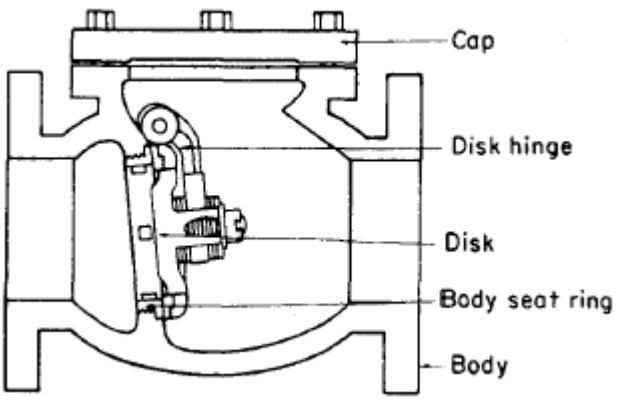


Lift check valve



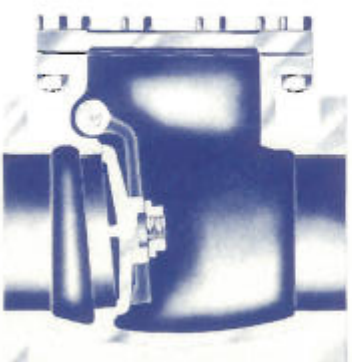
- *SWING CHECK VALVE*

Swinging action of disk operates these valves. The pressure of the fluid lifts the hinged disk & allow the flow. The disk return to seat by its own weight when there is no flow. It can be used in both horizontal & vertical position.



SWING CHECK VALVES

(COURTESY JENKINS BROS—VALVE MANUFACTURERS)



Outside Lever & Weight for swing check valve

(COURTESY WALWORTH CO.)

- WAFER CHECK VALVE

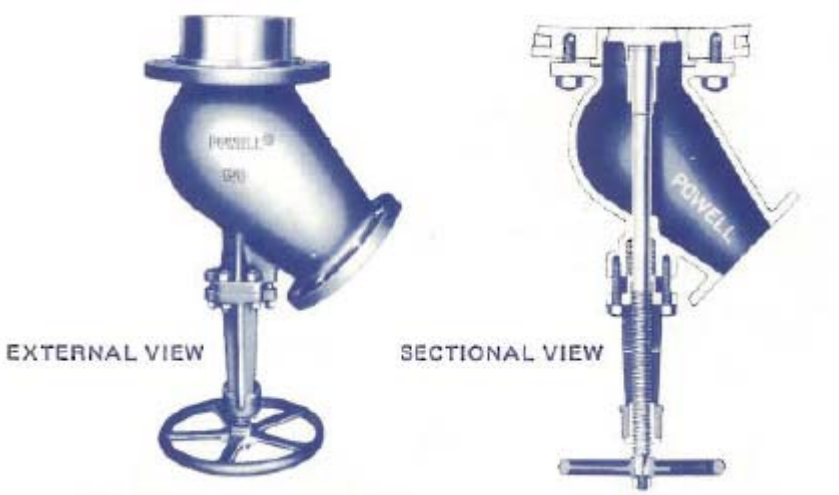
These are the flangeless swing check valves. There are two type of wafer check valve

i. Single plate wafer check valve
ii. Dual plate wafer check valve

- Wafer check valves are available from 2" to 48"
- Covered under the regulatory code API 594.
- Compact in design.
- Less pressure drop across the valve.
- Less water hammering.

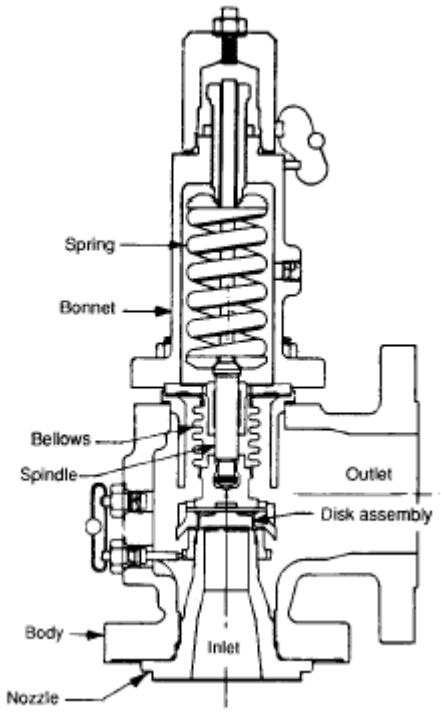
FLUSH - BOTTOM VALVE.

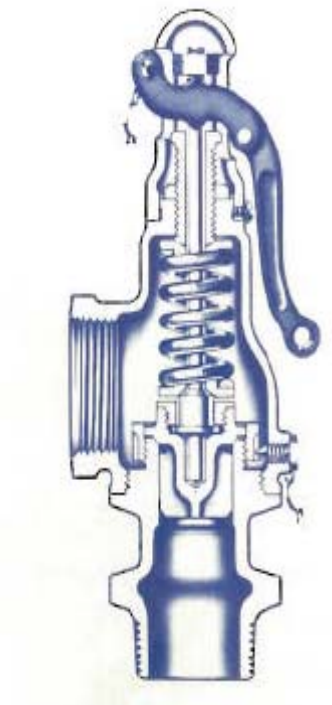
- Usually it's a globe valve type.
- Used to drain out piping, vessel, reactor.
- The disk in close position matches with the bottom surface of tanks or piping.
- Usually inlet is one size higher then the outlet size.
- The outlet port is at an angle of 45º- 60º to the inlet port.
- Available in the size range of 1" - 12".
- Available maximum rating of #300.



SAFETY VALVE.

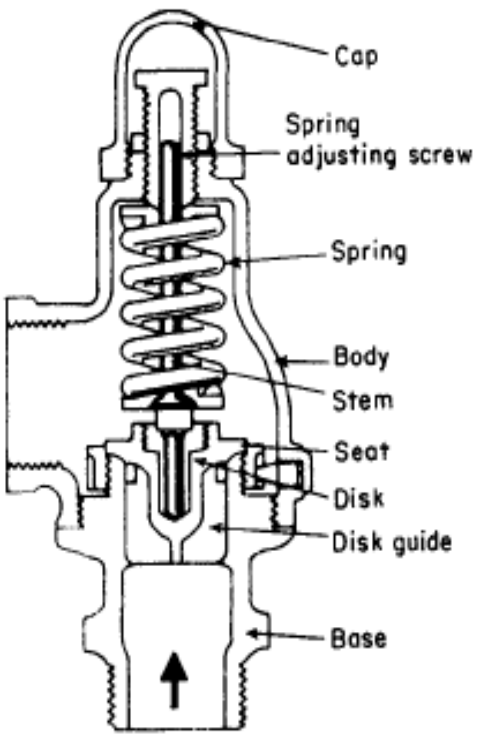
- An automatic pressure relieving device actuated by the static pressure upstream of the valve. Characterized by rapid full opening or pop action.
- Used for steam gas or vapor service.

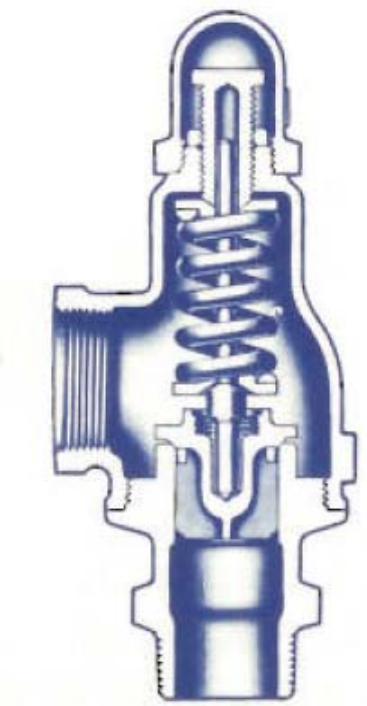




RELIEF VALVE.

- An automatic pressure relieving device actuated by the static pressure upstream of the valve. Which opens in proportion to the system pressure. Also the valve reseat when the pressure is reduced below the set pressure.
- Used primarily in liquid service.



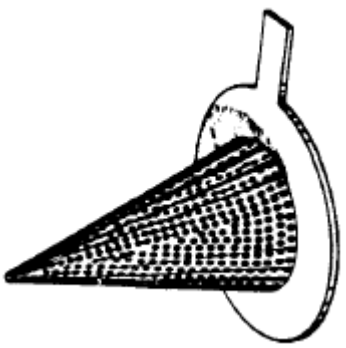


SPECIAL PARTS

STRAINERS

Strainers are used in a piping system to protect the equipment sensitive to dirt or other solid particle that may be carried by fluids.

During start-up temporary strainers are placed upstream of pumps to protect from construction debris, which may be left over during construction these are called **Start-up /Temporary strainers.**

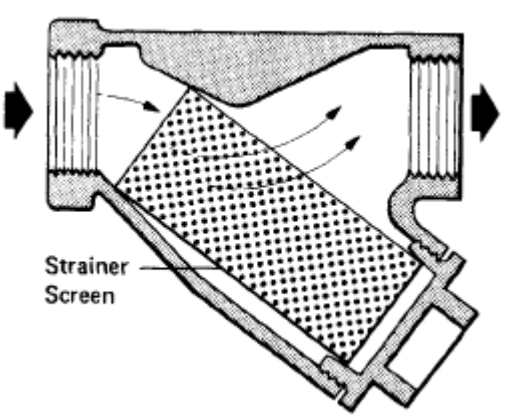


Conical Start-up temporary Strainer

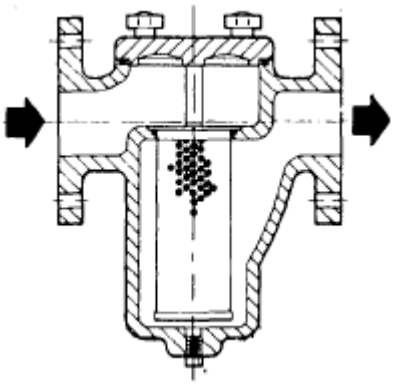
Permanent strainers are installed upstream of control valves, stream trap & instrument to protect it from solid particle.
There are two type of permanent strainer.

- Y- type strainer.
- Basket strainer.

Y-type strainer.



Basket strainer.



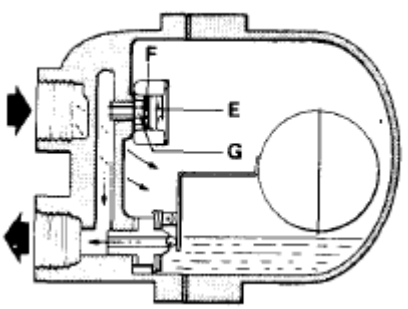
STEAM TRAPS:

The function of stream trap is to discharge condensate from the steam piping without releasing steam. Commonly used steam traps are

i. Float
ii. Thermostatic
iii. Thermodynamic
iv. Inverted bucket.

FLOAT

Float type consist of a chamber, containing float & arm mechanism, which modulates the position of discharge valve. When the level of condensate increases, the float lifts ups causing the valve to open & discharge condensate. This has got venting system to discharge air & carbon dioxide.

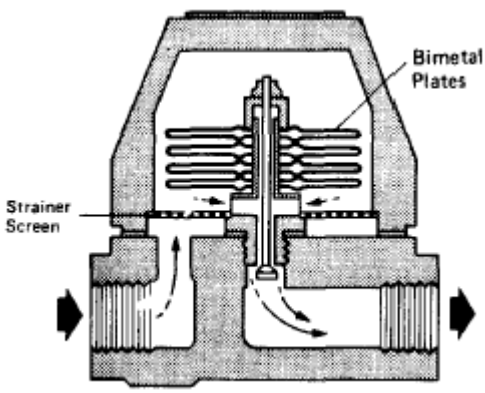


Feature

- Can be used in process, utility as well as HVAC system
- Generally used for high capacity.
- Not suitable when there is a fluid hammering in the system.
- Not suitable for very low temperature service.
- Available in size 15, 20, 25, 40, & 50 NB.
- Available in screwed, socket weld & flanged ends.

THERMOSTATIC

This system employs a thermostatic (Bi-metallic) elements, which opens & closes the valve. The valve gets open by cooler condensate & gets closed when steam comes in contact with the thermostatic elements.

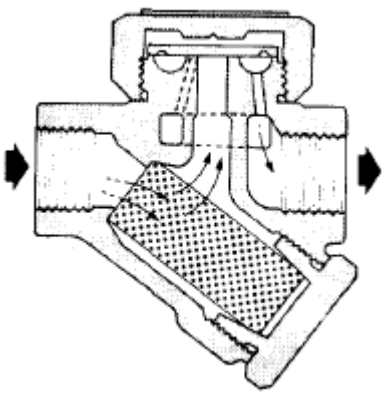


Feature

- Can be used where fluid hammering is anticipated in the piping system.
- It can handle wide range of condensate load over a wide range of pressure.
- The application include drip legs, heating coil, steam tracer etc.
- It requires a straight pipe run of 2" – 18" on upstream side.
- Available in size 15 & 20 NB.
- Available in screwed & socket weld ends.

THERMODYNAMIC

The basic principle behind this trap is that the expanded volume of steam compared to condensate has a throttling effect at the orifice. With the a properly sized orifice, condensate at lower specific volume will pass through the opening at comparatively slower velocity. As steam begin to reach orifice plate the condensate will begin to expand. As the condensate expand, the velocity through the orifice will increase & throttling action will start to take place.

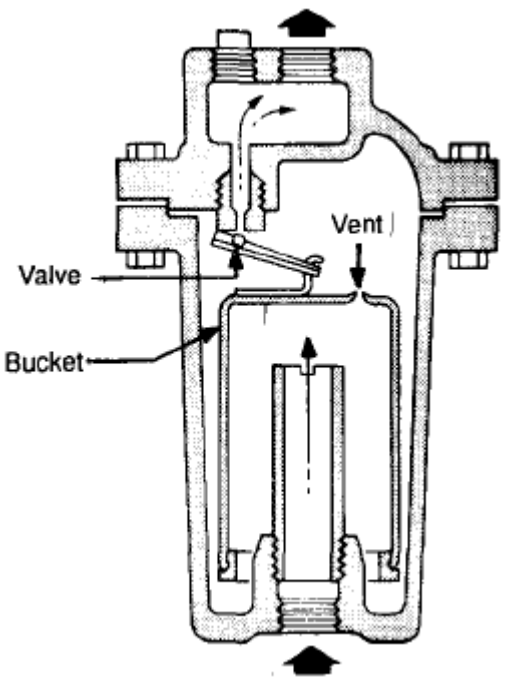


Feature

- Limited capacity.
- Potential for steam leakage.
- If steam is allowed to pass through the orifice for extended period, it will cause erosion of orifice.
- Available in size 15 & 20 NB.
- Available in screwed & butt welded ends.

INVERTED BUCKET

It consists of a chamber containing an inverted bucket, which actuates the discharge valve through linkage. The valve is open when bucket rest at the bottom of trap. This allows air to escape until the bottom of bucket is seal by rising condensate. The valve remains open as long as condensate is flowing, and trapped air bleeds out through a small vent in the top of the bucket. When steam enters the trap, it fills the bucket, causing the bucket to float, so it rises & close the valve.



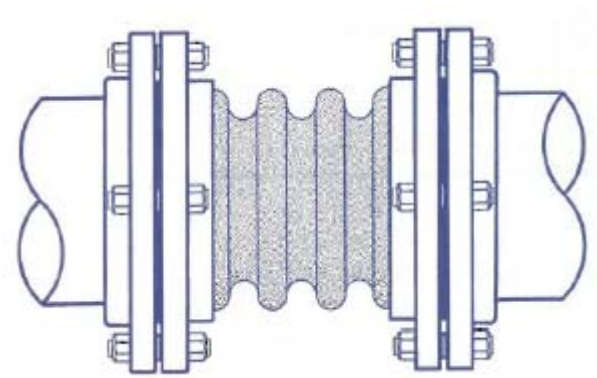
Feature

- Can be used over wide range of pressure & temperature..
- Available in size 15,20 & 25 NB.
- Available in screwed ends.

FLAME ARRESTOR:

A flame arrestor is a device that is fitted into, or at the end of, a pipeline or vessel where flammable gases or vapors are flowing. It prevents the transmission of accidentally ignited flames or explosions while permitting the process gas to flow. Flame arrestors may be installed on their own or as part of a more comprehensive flame and explosion safety system. More than one flame arrestor may be required to ensure complete protection.

EXPANSION BELLOWS:



An expansion bellows is a device used to allow movement in a piping system while containing pressure & the medium running through it.

The Bellows are generally employed in a piping system in one of the following situations:

- When the space constraints do not permit providing adequate flexibility by conventional methods (e. g. expansion loops etc.) for maintaining the system stresses within acceptable limits.
- When conventional solutions (e.g. expansion loops etc.) create unacceptable process conditions (e.g. excessive pressure drop).
- When it is not practical to limit the piping induced loads on the terminal nozzles of the connected equipment within admissible limits by conventional methods.
- When the equipment such as Compressors, Turbines, Pumps etc. necessitate isolating the mechanical vibrations from being transmitted to the connected piping.

PLOT PLAN

DEFINATION

Plot is the master plan locating each unit / facility within the battery limit for a process industry. It shows all the equipment & supporting facility like pipe rack, buildings etc to the scale. Usually this arrangement is shown in the plan views.

BASIC DATA / INFORMATION REQUIRED FOR DEVELOPING PLOT PLAN

i. Civil information

- Site location
- Contour survey map.
- Soil survey

ii. ***Process data***

- Process units & their capacities.
- PFD
- Project design data.
- Equipment list.
- Equipment size.
- Type of plant. Indoors or out door.
- Nature of plant.
- Operating philosophy
- Material handling philosophy.
- Storage philosophy.
- Number of flares.

iii. ***Metrological data.***

- Minimum & maximum temperature.
- Wind direction & its intensity.
- Rainfall.
- Seismic information.
- Flood level.

iv. ***Utility data.***

- Source of water supply & supply point
- Requirement of different kind of utilities like Steam. Air, nitrogen, DMW, Cooling water, chilled water etc.
- Grouping philosophy for utilities.
- Electrical supply point.

v. ***Non-plant facility.***

- Administrative block.
- Workshop
- Canteen.
- Laboratory.
- Vehicle parking
- Warehouse.
- Scrap yard
- Fire station
- Staff colony

vi. ***Statutory requirement.***

- State Industrial Development Corporation. (SIDC)
- Central / State Environmental pollution control board.(PCBS)
- Factory inspectorate
- State electricity board.(SEB)
- Chief controller of explosive. (CCOE)
- Static & mobile pressure vessel rules. (SMPV)
- Tariff advisory committee. (TAC)
- Aviation law
- Chief inspector of boiler.(CIB)
- Oil industry safety directorate. (OISD)
- Food & drug administration. (FDA)
- Ministry of environment & forest. (MoEF)

TYPES OF PLOT PLAN

i. ***Grade mounted horizontal arrangement***. In this type equipment is generally located on either side of central pipe rack, served by the auxiliary road. Main advantage of this arrangement is that all the equipment is on the grade, which makes it easier for construction, maintenance & operation. Disadvantage is that it require huge amount of real state.

ii. ***Structure mounted vertical arrangement.*** In type equipment is arranged vertically in the multistoried steel or concrete structure. Advantage is that it requires less amount real state. But require construction, maintenance & operation are not so easy. It require crane, trolley beam for equipment assess.

PLOT PLAN DEVELOPMENT

i. The block dimension of all the plant & non-plant facility is worked out considering expansion philosophy.

ii. Contour map is studied to establish the grade levels.

iii. Plant North in relation to geographical north is established.

iv. N-S, E-W (X-Y) grid is established at 10 meter each.

v. Following points to be considering while placing this block on plot plan.

- The process block should be placed in sequential order of process flow so that piping is minimum.
- Process block should be placed considering wind direction. So that flammable gas could not reach the source of ignition.
- Process block should be centrally located.
- Utility block should be close to process block.
- Group storage tank as per process classification.
- Centralized control room should be located at a safe place near to the process plant.
- Two adjacent process unit location shall be decided based on the annual shut down philosophy for the maintenance of the units.
- Electrical sub station should be at the center for minimum cabling.
- Process unit should be located at higher ground level served by peripheral road.
- Warehouse should be located close to material gate to avoid truck traffic within the process area.
- Locate fire tanks near to main gate.
- Provide two gate one for man entry and other for material handling.

- Effluent plant shall be located away from the other units on the down wind location. The preferred location is at lower elevation than the other plant units in order to facilitate gravity flow.
- Fire station and firewater pump house should be at a safe place away from hazardous areas. Fire station shall be near to the main gate with straight approach to process units and other critical areas.
- Flares, Furnaces/Heaters, Dusty operations and Cooling towers should be oriented depending on the prevailing wind direction. The first two should be located upwind of Process units and the last two on the down wind directions of process units.
- Flare location 90 meter away from any process unit in downward of wind direction.

- Due consideration of construction and erection of the plant shall be given while deciding the plant layout, especially Tall Towers, Reactors, Furnaces, etc. shall not be at congested areas and sufficient open space shall be provided to have erection at any stage.
- Equipment requiring frequent maintenance shall have easy accessibility. So also equipment having removable parts shall have free access for removal of the part and also for the free access for hoisting equipment.
- Green belt should be 1/3 of the plot area.
- Provisions for future expansion shall be considered. Usually 50%
- Inter space distance should be as per statutory authorities guidelines.

Some of the major distances to be considered during plant layout are given in Table

1.	Process Units to Flare	90 M
2.	Electrical Sub stn. to Process units	15 M
3.	Fire stations to Process Units — 60 M	
4.	Boiler House to Process Units — 45 M	
5.	Cooling Towers to Boundary	30 M
6.	Service Buildings to Process Units	60 M
7.	Control Room to Process Unit	30 M
8.	Process Unit to Process Unit	30 M
9.	Process Unit to ADM Building	60 M

Note:- Show one example of plot plan in the class.

EQUIPMENT LAYOUT

INTRODUCTION

Equipment & piping arrangement is an art not a science. There is no single formula for the design of equipment or piping layout. However systematic method & procedure can be developed based on the engineering principles, specification, practical experience & common sense.

STEPS INVOLVED IN PLANT DESIGN

vii. Conceptual layout.

This is basically a process requirement. In this only the essential process design requirement is established. Vertical & horizontal relation of equipment is spelt out. In this the basic size of unit , building or structure is worked out considering access for operation , maintenance & construction. Plans along with necessary section are shown normally in small scale of 1:100 or 1:200.
This is the basic document prepared at layout stage so proper thought must be given while generating it.

viii. ***Equipment layout.***

Basically this is an extension of conceptual layout in more detail. All the equipment & the facilities that require floor space are shown. Access, removal area, maintenance area, storage area are outlined.
The scale can be 1:50 on any size of sheet, depending upon the area coverage. If most of the equipment are of large size then scale can be reduced to 1:100, 1:200 or 1:250 e.g. in case of big tank farms, ammonia storage tanks, etc.

ix. ***Piping layout.***

- Minimum & maximum temperature.
-

BASIC CONSIDERATION FOR EQUIPMENT LAYOUT.

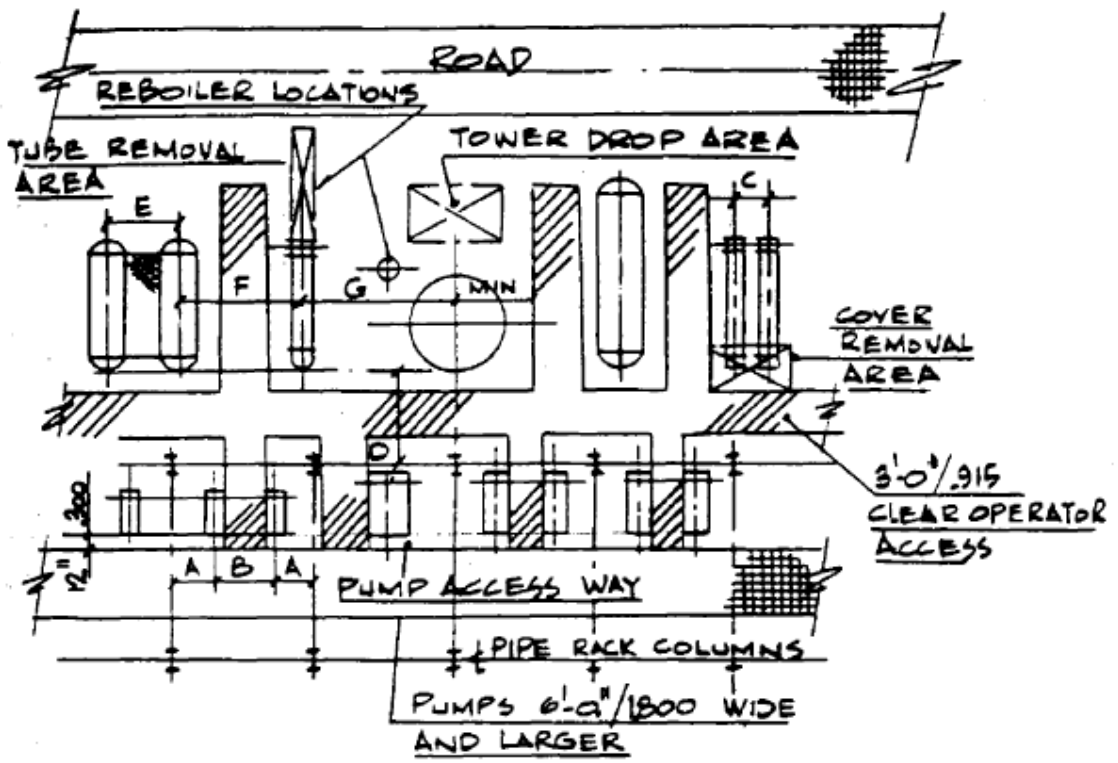
- Process requirements like minimum elevations, distances, slopes, etc.
- Ease of operational, maintenance & construction.
- Consideration must be given for monorail, crane, forklift for lifting of heavy equipments.
- Industrial safety.
- Statutory regulations e.g. Petroleum Act/ Gas Cylinder Rules, Static & Mobile Pressure Vessel Rules and Factory Inspectorate Rules.
- Economy, e.g. shortest piping, smaller floor space, etc.

EQUIPMENT SPACING.

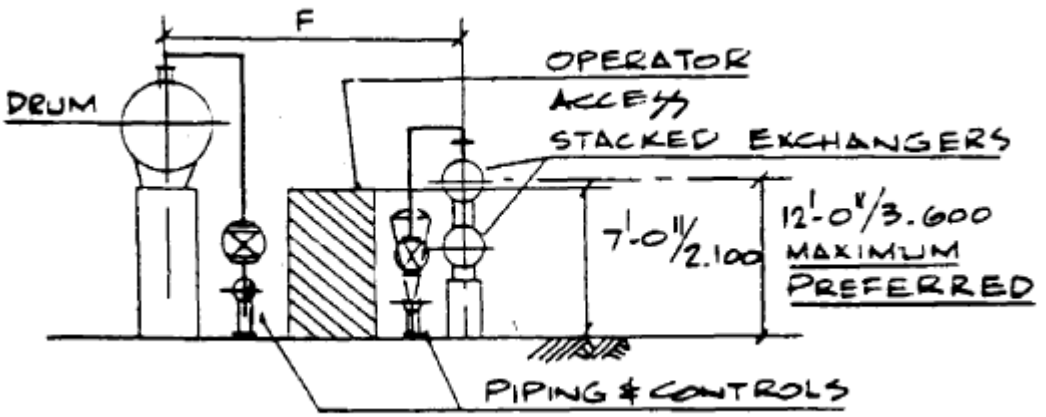
Spacing of the equipment within the unit is very important exercise. Here the designer must rely on the experience because at this stage final information is not available for calculating the distance between the equipment.

Some thumb rules are followed for equipment spacing of particular unit which are discussed below

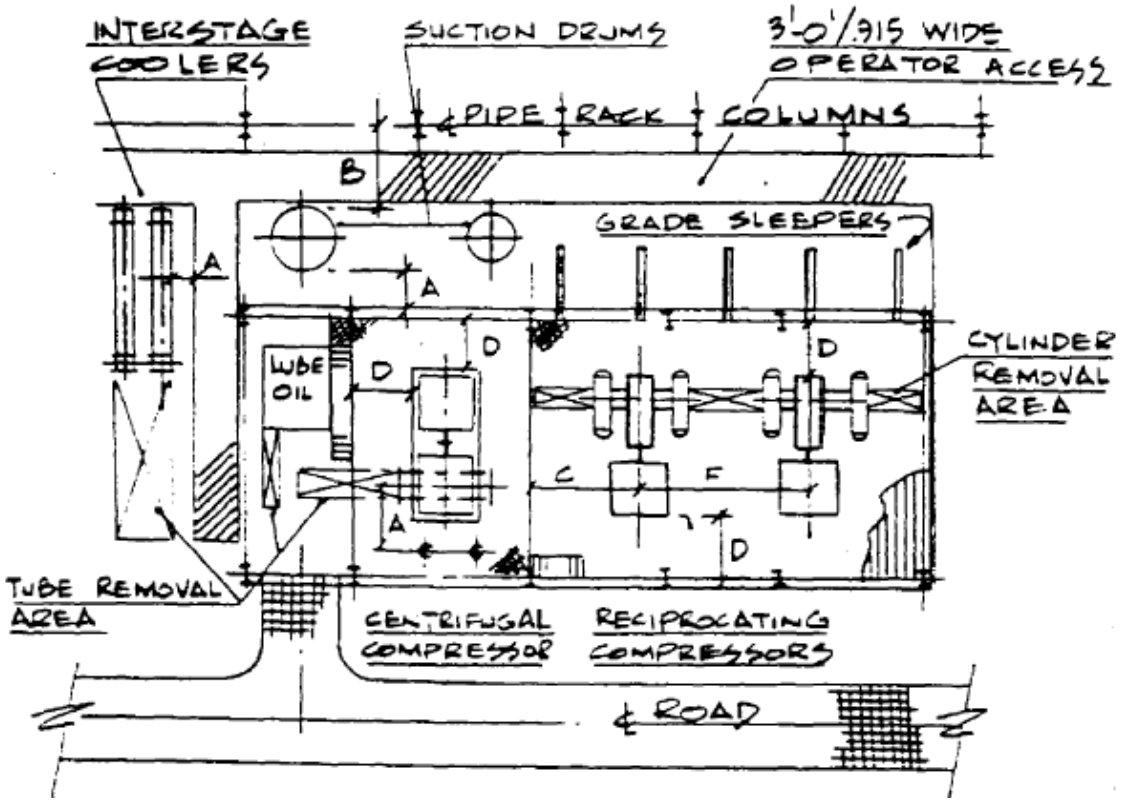
TYPICAL TOWER AREA SPACING



A	5’/ 1500MM
B	10’/ 3000MM
C	½ diameter of exchanger flanges + 18”/ 450.
D	8’ / 2400 - 10’ / 3000
E	½ diameter of drum + 4’/ 1200
F	½ drum diameter + ½ exchanger diameter + 3’/ 915(operator access) + 3’ /950 for piping & controls.
G	Minimum for flexibility

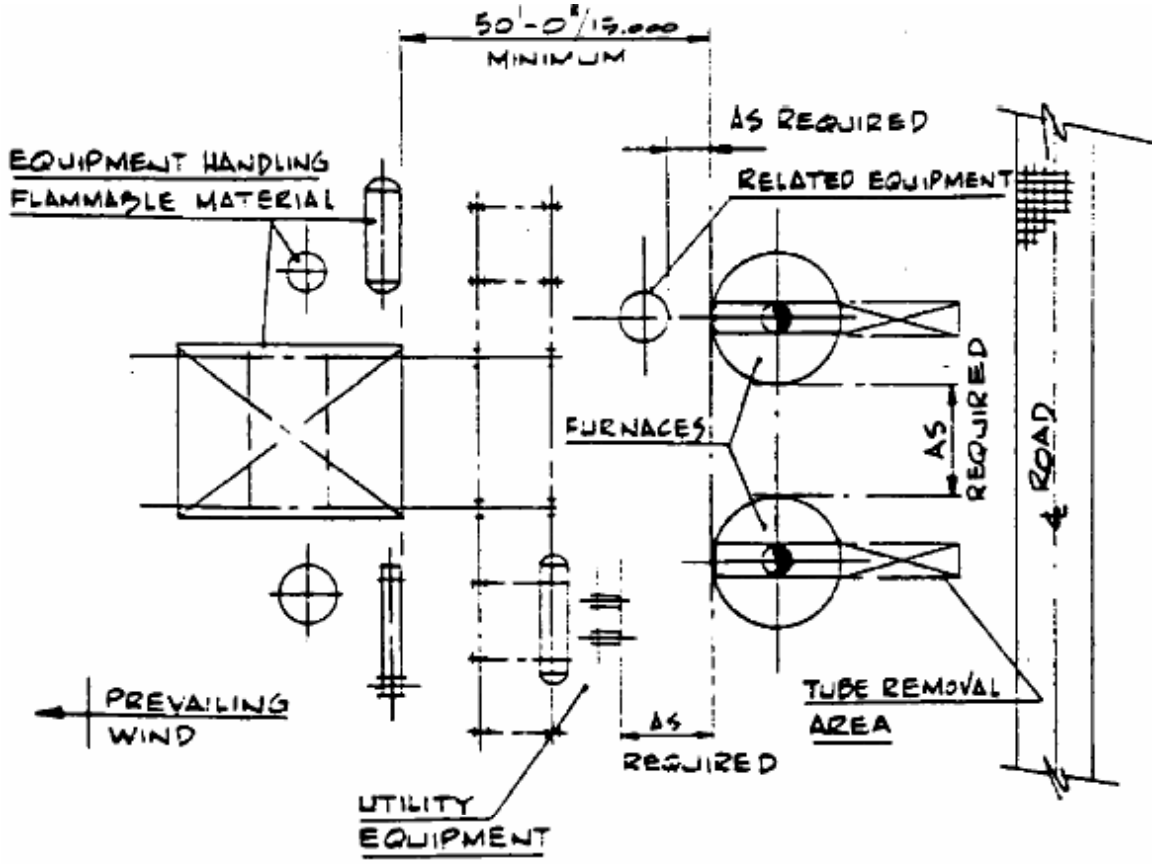

F
DRUM
OPERATOR
ACCESS
STACKED EXCHANGERS
7'-0 11/2.100
12'-0"/3.600
MAXIMUM
PREFERRED
PIPING & CONTROLS

TYPICAL COMPRESSOR AREA SPACING



A	Minimum
B	8'/ 2400MM
C	Cylinder removal + 12"/ 300.
D	6'/ 1800 minimum
F	2 x C + 18'/ 450

TYPICAL FURNACE AREA SPACING



EQUIPMENT SPACING

Distillation Column to Furnace	20 M
Gas Compressor to Furnace	25 M
Distillation Column Compressor to gas	7.5 M
Between Pumps	3 M
Between Heat Exchangers	1 M
Control room to Furnace	30 M
Between Pressure Vessels	1.5 M
Air fin Cooler to Control room	15 M
Reactor to fired heater	10 M

ACCESS CLEARANCES

DESCRIPTION	**MINIMUM**		
	Clear Headroom	**Clear Width**	**Other Clearance**
Primary Access Roads (carrying major equipment)	6M	6M	10.5M inside corner radius
Secondary	5M	4.8M	4.5M inside corner radius
Minor Access Roads	5M	3.6M	-
Yard Piping	3M	-	-
Platform, walkways, passageways, working areas, stairways	2.2M	1M working platforms	-
Clearance from face of manhole	2.1M	1M	Manhole center Approx. 1M above platform

ELEVATION

Open-Air Paved Area High Point of Paving	100.000M
Underside of base plates for structural steel	100.150M
Stair and ladders pads	100.075M
Underside of base plates vessel and column plinths	100.300M
Top of pump plinths	100.230M

MAINTENANCE FACILITIES

EQUIPMENT	PART HANDLED	HANDLING FACILITIES
Reactors, Vessels and Columns.	Manhole Covers	Davits or hinges for swinging open.
	Internal requiring regular removal or servicing.	Trolley beams or davits for lowering from holes to grade.
	Fixed bed reactors, catalyst change, etc.	These will be provided as specially specified to enable catalyst to be offloaded and loaded.
Floating Head Exchangers.	Tube Bundles.	All such exchangers are provided with jackbolts to break joints. It is assumed bundles will be handled by mobile equipment.
	Exchanger Heads, Channel Cover, Bonnets.	No special provision.
Vertical Exchangers.	Removable Tube Bundles.	Overhead trolley beam or davit.
Pump.	Any part.	None.
Centrifugal Compressors.	Rotating parts.	Overhead trolley beams or cranes.
Piping.	Relief Valves, 2” nominal bore and larger.	Hitching point or davit for lowering to grade.

	Blanks, blank flanges and swing elbow weighing more than 300lbs (125 kg).	Overhead hitching point or davit only when subject to frequent removal for maintenance.

GUIDE LINES FOR EQUIPMENT LAYOUT DRAWING

- Equipment layout should be drawn in the scale of 1:50 or 1:100.
- Generally drawn on A0 sheet , if area is small A1 sheet can also be used.
- North direction should be shown top right corner .
- The area above Title block should be kept free for general notes & reference drawings.
- Each Unit Plan to have a key plan of overall G.A. highlighting the area covered by that Unit Plot Plan.
- All equipment should be marked with Tag no.
- All the equipment items should be located by co-ordinates of center lines or dimensions from a column center line. Orientation of equipment should be given by locating one big size nozzle usually manhole in plan and elevation. Only elevations should be given. No vertical dimension lines will be added. All elevations should be with respect to +0.00 meters and should be finished elevations.
- Walkways ,cutout ,pipe rack , surrounding road , platform , stair, ladder ,trench. drain etc should be clearly shown.
- If required section drawing of equipment should be shown.
- Each floor level should be shown separately.
- Provision for future equipment should be shown by dotted lines.
- Maintenance , cleaning & tube removing area should be clearly marked .
- If layout is continued to another sheet then match line should be marked with the continued drawing no.

PIPING LAYOUT

PIPING PLAN DEVELOPMENT.

Normally piping layout is developed in two stages

- Piping study plan
- Final piping plan.

Piping study plan:- *It is basically a conceptual routing of pipelines based on P&ID . All the condition laid down in P&ID is fulfilled. . Routing is represented in plan views , sometime section is shown wherever its required. Piping layout shows all lines 2" & above, sometime critical small bore lines can be shown. Study layout starts with routing of critical lines first. Critical lines are those which are either having large diameter, high temperature or gravity flow*

Final piping plan:- Piping study plan along with the isometric is discussed with other department in order to get their comments. Now their comments are incorporated to freeze the piping study layout to be called as final piping plan. This document is used for construction.

INPUTS REQUIRED FOR PIPING LAYOUT

- P&ID
- PFD
- Vendor drawing/catalogue information for equipments
- Piping specification.
- Plot plan
- Equipment layout.
- Design guide line / Standards.
- Instrument hook-up drawing

GUIDE LINES FOR DEVELOPMENT OF PIPING LAYOUT.

- Process requirements indicated in P& ID should be meet.
- The lines should be routed in orderly manner. Line should be grouped in bunch & run together where ever possible for the ease of supporting.
- Only the standard Pipe , fittings, special parts mentioned in pipe specification should be used for routing. Anything outside the Spec is not permitted.
- Over head piping should have clear headroom for man ways, & movement of cranes ,trucks where applicable.
- Piping on the grade level should be minimized as it blocks the free movement.
- The piping component that requires frequent maintenance should be easily accessible from grade or platform & should have adequate clear working space.
- Piping should be routed so as to allow removal & lifting of equipment with minimum pipe dismantling.
- Pocket should be avoided especially in relief & steam lines.
- Hot lines should be routed to have some flexibility in the form loops.
- All critical lines should be stress analyzed.

PIPING FOR INSTRUMENTS.

i. ***Orifice Flange***:-

- It is located at a convenient place, which could be accessible by temporary ladder.
- Orifice is always preferred in the horizontal run.
- Tapping for instrument connection is usually at 45° either at top or bottom.
  For liquid service Tapping is downward direction.
  For Gaseous service tapping is upward direction.

- Use of valve & fittings makes the flow more turbulent which affect the measurement accuracy hence straight run are recommended upstream & down stream of orifice. This straight run is expressed in terms of pipe dia. For e.g 10D , 20D. This straight run is indicated in the P&ID else it can be obtained from process department.

ii. ***Control valves:-***

- Generally control valve assembly shall be located on the grade level
- Preferably control valve should be on horizontal run.
- Control valve placed on vertical run require proper support for its actuator.
- By-pass line routed over control valve should have proper clearance over the actuator.

iii. ***Thermo wells:-***

- Termowell are used to measure temperature of fluid service either by locally mounted indicator or through transmitters
- Thermowell can either be located on the elbow or on the straight run pipe.
- To mount thermowell on elbow. The minimum size of elbow should not be less than 3" & orientation shall be in the opposite direction of flow.
- To mount thermowell on straight pipe, minimum pipe size should be at least 4". Some licenser consider it 6" or 8". It depends on the size of instrument filament.
- Correct nozzle projection from O.D of pipe is very important so that the correct portion of filament comes in contact with the fluid. Normally it should me 150mm for the bare pipe. Consider the insulation thickness for insulated lines.

iv. ***Safety valves:-***

- Safety valve should be easily accessible.

- Safety valve inlet piping should be kept as short as possible.

- Safety valve outlet piping should be self draining to relief header.

- When Safety Valves discharge vapors to the atmosphere, the outlet pipe should terminate at least 3 meters above equipment or any service platform located within a radius of 15 meters of the valve. A 3/8" dia weep hole for drainage at low point of line should be provided. Also the top open end should either be provided with a rain hood or with a 45 degree elbow and open end cut vertically.

- When Safety Valves discharge steam to the atmosphere, the outlet pipe should terminate at least 3 meters above any service platform located within 8 meters of the valve. Outlet pipe should have a 3/8" weep hole for drainage at low point of line should be provided. Also the top open end should either be provided with a rain hood or with a 45 degree elbow and open end cut vertically.

- Provision of lifting devices such as davit, chain pulley block should be made for all relief valves weighing more than 45 Kgs.

- Relief header shall not have pocket. Where this requirement cannot be met., Process engineer should be consulted for making provision of a knock out pot.

- Safety Vales invariably require strong and sturdy special supports in order to absorb thrust. Also, the branches for inlet to Safety Valves are usually reinforced. Normally, a fixed type of support is provided close to Safety Valve and with this in mind main line should be routed in such a way so as to have enough flexibility.

ARRANGEMENT OF VALVES.

- All valves should be located at easily accessible position for the ease of operation & maintenance.

- Preferably valve should be located with the stem in vertical position for the ease of maintenance & minimum blockage of operating area.

- Valves located on the horizontal run can have stem rotated to horizontal position but preferably should not be lower than horizontal.

- Valve size greater than 12" is normally gear operator.

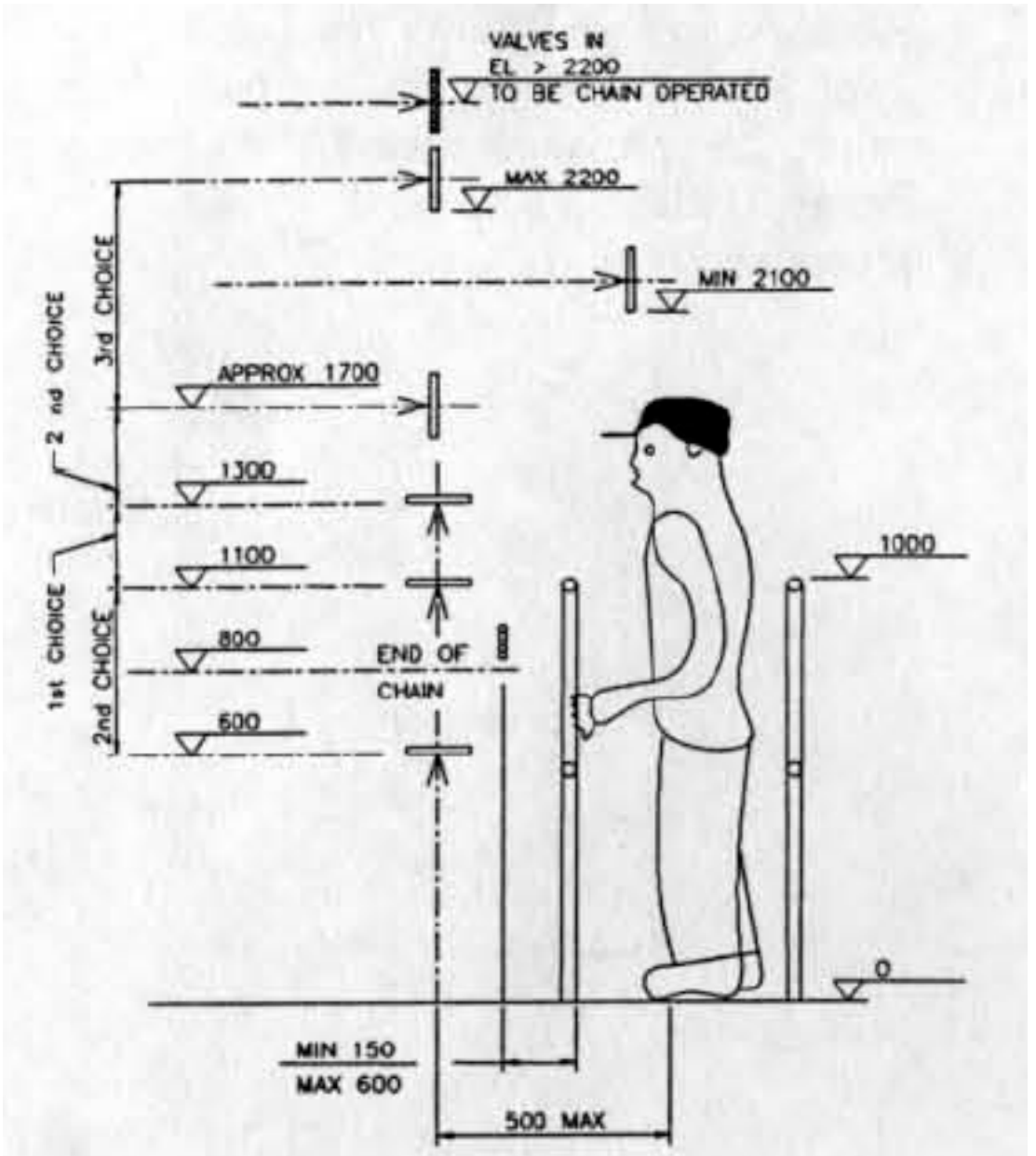
- Care must be given while locating gear operated valve. Hand wheel should be on operator side. check for the interference of gear box with other pipe or structure.

- Care must be given while locating motor operated valve. Hand wheel should be on operator side. check for the interference of actuator assembly with other pipe or structure.

- All valves located above 2.2M should be chain operated. For chain operation valve stem shall be in horizontal position.

- Valves located below the grade level due to process consideration are usually provided with extended spindle for operation.

- Location of check valve in horizontal or vertical depends upon its internal construction. **Swing type** can be either in horizontal or vertical. **Lift type** can only be in horizontal position.


VALVES IN
EL > 2200
TO BE CHAIN OPERATED
MAX 2200
MIN 2100
APPROX 1700
1300
1100
800
600
END OF
CHAIN
1000
0
MIN 150
MAX 600
500 MAX
3rd CHOICE
2 nd CHOICE
1st CHOICE
2nd CHOICE

ARRANGEMENT OF STRAINERS.

- ***Y or T Type strainer:-*** This is located in the horizontal run of pipe. As the name suggest the shape of strainer is in the form of Y & T respectively. It contains a removable screen from the bottom hence it is rotated to 45° or sometime 90° to facilitate easy removal of screen.

- ***Conical strainer:-*** For installation of conical strainer a spool piece equal to the length of conical screen is required

- ***Basket type strainer:-*** Usually this type of strainer is big in size & screen is removed from the top hence sufficient clearance should be kept above it.

ARRANGEMENT OF REDUCER.

The choice of eccentric or concentric reducers should be made correctly. In order to simplify the situation following is recommended.

- All reducers located in vertical run should be Concentric reducer.
- All reducers located in horizontal run should be Eccentric.
- Eccentric reducers depending upon the position can be placed with flat side either on top or bottom.
- Usually, at all pump suctions, eccentric reducers have flat sides on top except for pumps handling slurry where eccentric reducers are placed with flat sides on bottom.
- At all pipe rack locations, eccentric reducers are used with flat sides on bottom in order to keep BOP same.
- At control valve assemblies, eccentric reducers can be placed with flat sides on bottom.

NOTES.

- Line routed on grade level should have common BOP, which is governed by nozzle elevation of the equipments & the drain requirement. There should be 150mm clearance between the drain valve & paving.

- For the steam header lines on pipe rack steam trap is provided for every 30meters of straight run. Usually they are located near the rack column for the ease of supporting small bore lines connected to steam trap.

- Steam lines should be provided with low point drain & high point vent.

- Expansion bellows are installed in piping where it is not possible to have in built flexibility due to process reasons.

- Condensate discharge piping for a closed system should have minimum number of bends. This is to avoid high back pressure acting on traps.

PIPING LAYOUT DRAWING.

Piping layout is generally generated on A0 paper size with the scale of 1 : 33.33.
A good piping layout drawing shall contain the following information in addition to what discussed in equipment layout. Chapter.

- Lines below 6" is indicated by single line .line size 8" & above is indicated by double lines.

- Each line should be designated with complete line no as in line list.

- All piping components & special items should be represented by its Tag no.

- Line is generally represented by center line elevation. Lines on rack or sleeper are represented by TOS/ BOP.

- Spec break should be clearly shown.

- Every line should have flow direction .

- All valves and piping should be represented by proper symbol.

- Valve center line elevation & orientations should be clearly mentioned.

- All lines should be fully dimensioned.

- All primary & secondary support should be clearly marked up.

- Battery limit & match line shall be shown clearly

PIPING STUDY
PIPERACK

INTRODUCTION

The pipe way conveys all main process lines connecting distant pieces of equipment, relief and blowdown headers, all lines leaving and entering the plant, utility lines supplying steam, air, cooling water and inert gas to the plant. Electrical and instrument cable trays are usually routed in the pipe way. Pipe ways are classified by their relative elevation to grade.

PIPE RACK

Overhead piping supported on steel or concrete columns.

PIPE TRACK

Above ground piping supported on concrete sleepers at grade level. (Off site areas where equipment is well spaced out)

INFORMATION REQUIRED FOR DEVELOPING PIPERACK

1) ***JOB SPECIFICATION*** :-Basically it is the design criteria, agreed between company & client.

- Battery limit, valving and spade requirements.
- Catwalk, platform and ladder access to valves and relief valves in pipe rack.
- Minimum headroom and clearances under overhead piping or supporting steel within areas
- Pipe ways and secondary access ways
- Main access roads
- Rail roads
- Standard to be used for minimum spacing of lines in paperacks
- Handling and headroom requirements for equipment positioned under pipe racks
- Operating and safety requirements affecting pipe rack and structure design
- Location of cooling water lines underground or above ground

2) PROCESS FLOW DIAGRAM :- Process flow diagrams show main process lines and lines interconnecting process equipment.

3) ***PIPING & INSTRUMENT DIAGRAM:-*** Engineering flow diagrams are developed from process flow diagrams and show:

- Pipe sizes. Pipe classes, and line number.
- Valving.
- Manifolding.
- All instrumentation.
- Equipment and lines requiring services, i.e. water steam, air, nitrogen etc.

4) UNIT PLOT PLAN/ OVERALL PLOT PLAN

5) UTILITY FLOW DIAGRAM:-

Utility flow diagrams show the required services:

- Steam
- Condensate
- Water
- Air
- Gas

STEPS TO RACK PIPING

i. The first step in the development of any pipe rack is the generation of a line-routing diagram. A line routing diagram is a schematic representation of all process & utility piping systems drawn on a copy of pipe rack general arrangement drawing / or on the unit plot plan. Based on the information available on the first issue of P&I Diagram / Process flow diagram

ii. Once the routing diagram is complete, the development of rack width, structural column spacing, and road crossing span, numbers of levels and their elevations should be started.

iii. Pipe rack column spacing shall be decided based on the economics of the pipe span as well as the truss arrangement to accommodate double the span for road crossing or avoiding underground obstructions.

iv. The pipe rack width can now be worked out with a typical cross-section of the rack with the levels.

v. Normally, pipe rack carry process lines on the lower level or levels and the utility lines on the top level. Instrument and electrical trays are integrated on the utility level if space permits or on a separate level above all pipe levels.

vi. Any pipe rack design should provide provision for future growth to the extent of 25 to 30% on the rack clear width.

vii. When flanges or flanged valves are required on two adjacent lines, the flanges are to be staggered.

viii. Thermal expansion or contraction must be accommodated by keeping sufficient clearance at the location where the movements will occur.

ix. The clearance of the first line from the structural pipe rack column is to be established based on the sizes furnished by the civil / structural engineers.

x. After analyzing all the requirements and arrangements, the dimensions are to be rounded off to the next whole number. Based on the economics, the width and the number levels e.g. two tier of 30 ft. wide or three tier of 20 ft. wide rack will be decided.

xi. The gap between the tiers shall be decided on the basis of the largest diameter pipeline and it's branching. The difference between the bottom line of pipe in the rack and the bottom of a branch as it leaves the rack shall be decided carefully, to avoid any interference due to support, insulation, size of branch etc. All branch lines from the main lines on pipe rack shall be taken aesthetically on a common top of steel (TOS). With the above considerations, the conceptual arrangement of pipe rack are to be finalized.

PIPE RACK WIDTH CALCULATION

The width of pipe rack is influenced by :

- The number of lines
- Electrical/instrument cable trays.
- Space for future lines.

The width of a pipe rack may be calculated using the following method : First estimate number of lines as described. Add up the number of lines up to 18" diameter in the densest section of the pipe rack. The total width in meters (W) will be :

W = (f x N x S) + A meters

Where f, safety factor = 1.5, if the lines have been laid out as described in initial evaluation.
Where f, safety factor = 1.2, if the lines have been laid out as described under development.
N = number of lines below 18" diameter
S = average estimated spacing between lines in millimeters.
Usually - S = 300 mm
Usually - S = 230 mm (if lines in pipe rack are smaller than 10")
A = additional width required meters for :

- Lines larger than 18".
- Future lines.
- Instrument and electrical cable trays.
- Any slot for pump discharge lines 500 mm - 1 meter.

The total width is thus obtained. If W is bigger than 9M usually two pipe rack levels will be required.

NOTE:

At the beginning of a job, `W` should usually include 30 - 40% of clear space for future lines.
The width of the pipe rack may be increased or determined by the space requirement, and/or access to equipment arranged under the pipe rack.

PIPERACK BENTS SPACING

A pipe bent consist of vertical column & horizontal structural member that carry piping system.
Normal spacing between pipe rack bents varies between 4.6M to 6M.
This may be increased to a maximum of 8M consideration must be given to :

- Smaller lines which must be supported more frequently
- Liquid filled lines requiring shorter span than gas filled lines
- Hot lines which span shorter distances than cold lines of the same size and wall thickness
- Insulated lines; small bore, cold - insulated lines due to weight of insulation must be supported at relatively short intervals
- Space requirements of equipment at grade can sometimes influence pipe rack bent spacing.

Size (inches)	Schedule (inches)	Corrosion Allowance	Vapor Line Insulation (Span)			Liquid Line Insulation (Span)			Bare Pipe (Span)		Size (inches)
			To 350° F	351° to 600° F	601° to 750° F	To 350° F	351° to 600° F	601° to 750° F	Empty (to 350° F)	Water Filled (to 350° F)	
3/4	40	0.05	12	11	8	12	10	7	14	13	3/4
1	40	0.05	14	13	10	14	12	9	16	14	1
1 1/2	40	0.05	18	14	14	17	15	12	19	17	1 1/2
2	40	0.10	18	16	11	17	15	11	21	18	2
2 1/2	40	0.10	23	19	16	19	18	15	25	21	2 1/2
3	40	0.10	24	21	18	21	19	16	26	22	3
4	40	0.10	27	25	22	24	23	19	29	25	4
6	40	0.10	33	31	28	29	27	25	34	29	6
8	40	0.10	39	36	33	33	32	29	40	33	8
10	40	0.10	44	42	39	37	35	34	46	38	10
12	3/8 w	0.10	47	45	42	39	38	36	49	40	12
14	3/8 w	0.10	49	47	44	40	39	37	52	41	14
16	3/8 w	0.10	53	50	47	42	41	39	55	43	16
18	3/8 w	0.10	56	54	50	44	43	40	59	45	18
20	3/8 w	0.10	59	57	53	46	45	41	62	46	20
24	3/8 w	0.10	65	62	58	48	47	43	68	49	24
3/4	80	0.10	12	10	7	11	10	6	14	13	3/4
1	80	0.10	14	12	10	13	12	9	16	14	1
1 1/2	80	0.10	17	16	14	16	15	13	10	17	1 1/2
2	80	0.10	19	17	14	18	16	13	21	19	2
2 1/2	80	0.10	22	20	18	20	19	17	23	21	2 1/2
3	80	0.10	24	22	20	22	21	19	25	23	3
4	80	0.10	27	26	23	25	24	22	29	26	4
6	80	0.10	34	32	30	31	29	28	35	31	6
8	1/2 w	0.10	39	37	35	35	33	32	40	36	8
10	1/2 w	0.10	44	42	39	38	37	35	45	39	10
12	1/2 w	0.10	47	45	43	41	40	38	49	42	12
14	1/2 w	0.10	50	48	45	42	41	40	51	44	14
16	1/2 w	0.10	53	51	49	44	43	42	55	46	16
18	1/2 w	0.10	57	55	52	47	46	44	59	48	18
20	1/2 w	0.10	59	57	55	49	47	46	62	49	20
24	1/2 w	0.10	65	63	60	52	50	49	68	52	24
1	XXS	0.25	14	13	10	13	12	10	15	14	1
1 1/2	XXS	0.25	17	16	14	16	15	14	18	17	1 1/2
2	XXS	0.25	20	18	15	18	17	15	21	19	2
2 1/2	160	0.25	21	19	17	19	18	16	23	21	2 1/2
3	160	0.25	24	22	20	22	21	19	25	23	3
4	120	0.25	27	26	23	25	24	22	29	26	4
6	80	0.25	33	31	28	28	27	26	35	29	6
8	1/2 w	0.25	38	34	33	32	30	40	34	8	8
10	1/2 w	0.25	43	41	38	36	35	33	45	37	10
12	1/2 w	0.25	47	45	41	38	37	35	49	39	12
14	1/2 w	0.25	49	47	44	39	38	37	52	40	14
16	1/2 w	0.25	52	50	48	41	40	39	55	42	16
18	1/2 w	0.25	56	53	50	43	42	40	59	47	18
20	1/2 w	0.25	59	56	53	45	44	42	62	45	20
24	1/2 w	0.25	64	60	58	47	46	45	68	48	24

PIPE SUPPORT SPAN CHART

PIPERACK BENTS SPACING

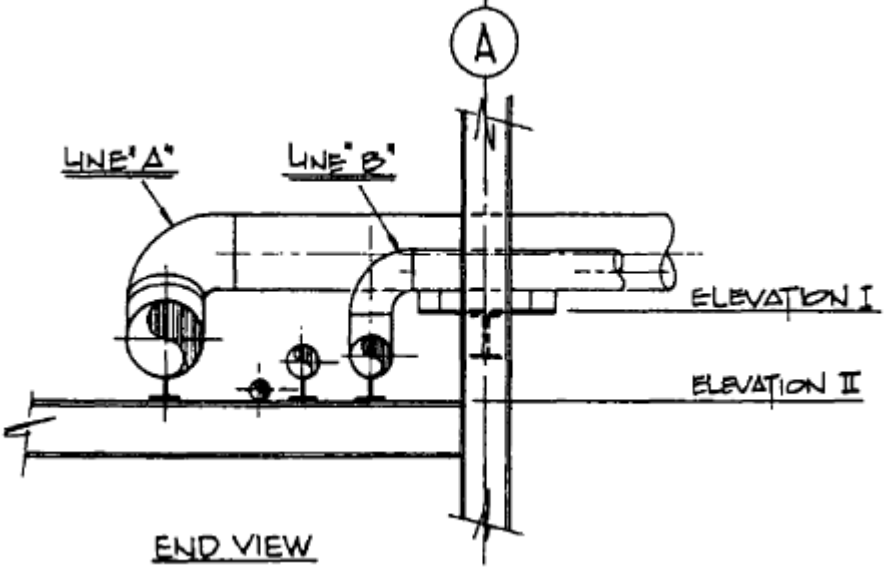
LINE SIZE	150# FLANGE													300# FLANGE											
ADJACENT LINE SIZE	1	1½	2	3	4	6	8	10	12	14	16	18	20	24	1	1½	2	3	4	6	8	10	12	14	16	18	20	24
1	7	7	7	7	7	8	9	10	12	13	14	15	16	18	7	7	7	7	7	8	9	10	12	13	14	15	16	18
1½		7	7	7	7	8	9	10	12	13	14	15	16	18		7	7	7	7	9	10	11	13	14	15	16	18	20
2			7	7	7	8	9	11	12	13	14	15	16	19			7	7	8	9	10	11	13	14	15	17	18	21
3				7	8	9	10	11	13	14	15	16	17	19				7	8	9	11	12	13	15	16	17	18	21
4					8	9	10	12	13	14	15	16	17	20					9	10	11	12	14	15	16	18	19	22
6						10	11	13	14	15	17	17	19	21						11	12	13	15	16	17	19	20	23
8							12	14	15	16	18	18	19	22							13	14	16	17	18	20	21	24
10								15	16	17	19	19	21	23								15	17	18	19	21	22	25
12									17	18	20	20	22	24									18	19	20	22	23	26
14										19	20	21	22	24										21	22	23	24	26
16											21	22	23	25											22	23	25	27
18												23	24	26												24	26	28
20													25	27													27	29
24														29														31

NOTES:
- SPACING IS BASED ON RADIUS OF PIPE TO FLANGE + 1"/.025.
- SELECT LINE WITH LARGEST FLANGE DIAMETER, FIND ADJACENT LINE SIZE & READ ACROSS TO FIND CENTERLINE-TO-CENTERLINE DIMENSIONS, IN INCHES.
- ADJUST DIMENSION TO SUIT INSULATION THICKNESS.
- CALCULATE SPACING WHERE PIPE RACK REAL ESTATE IS LIMITED.
- ADJUSTMENTS TO SPACING FOR THERMAL EXPANSION OR CONTRACTION MUST BE MADE.

PIPE RACK ELEVATION

Pipe rack elevation is determined by the highest requirement of the following :

- Headroom over main road
- Headroom for access to equipment under the pipe rack
- Headroom under lines interconnecting the pipe rack and equipment located outside.
- Rack take -offs & change of direction will generally be executed by change of elevation.
- The gap between the tiers shall be decided on the basis of the largest diameter pipeline and it's branching. The difference between the bottom line of pipe in the rack and the bottom of a branch as it leaves the rack shall be decided carefully, to avoid any interference due to support, insulation, size of branch etc. All branch lines from the main lines on pipe rack shall be taken aesthetically on a common top of steel (TOS).



LINE IDENDIFICATION

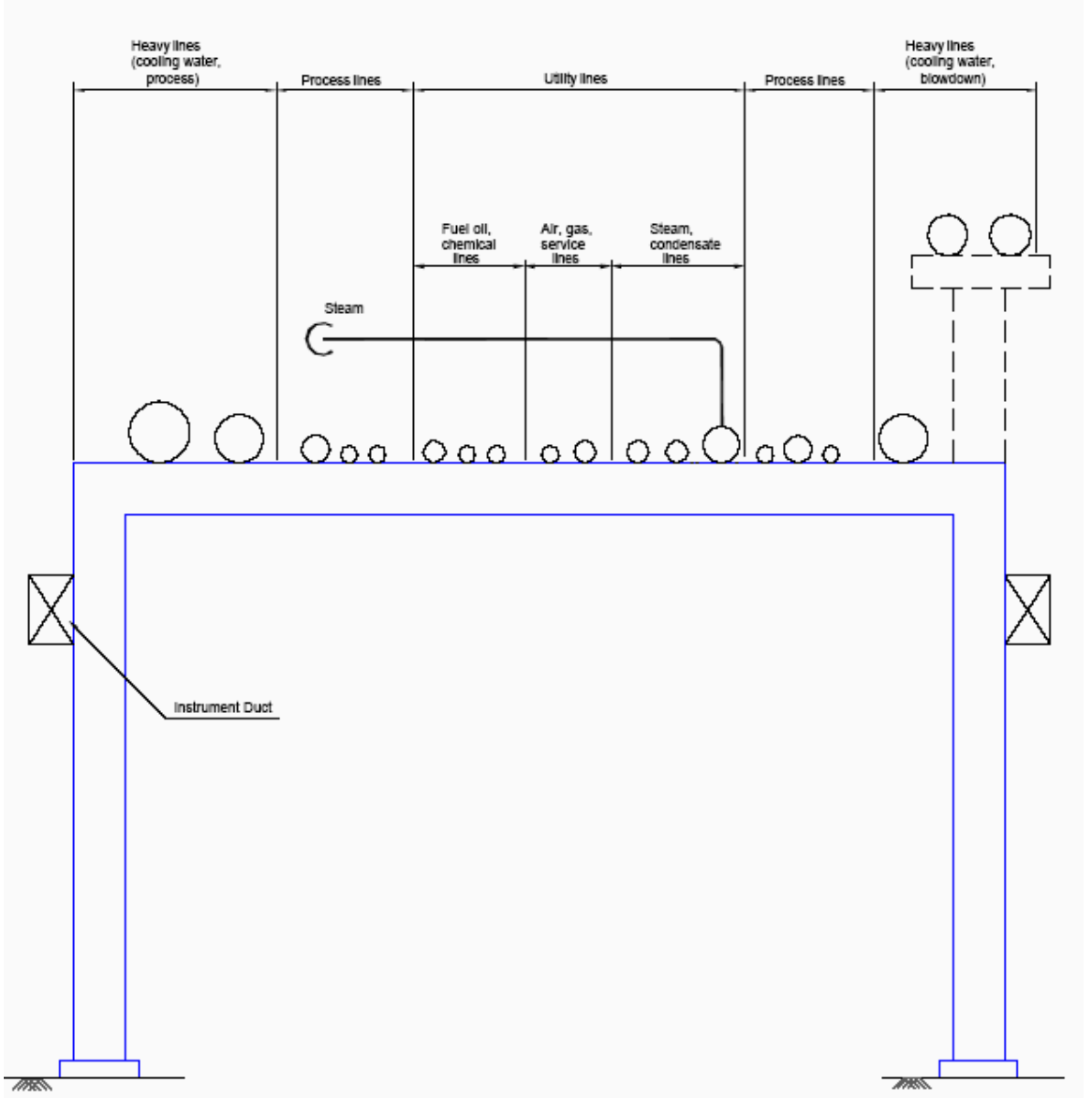
Pipelines in the pipe rack are classified as

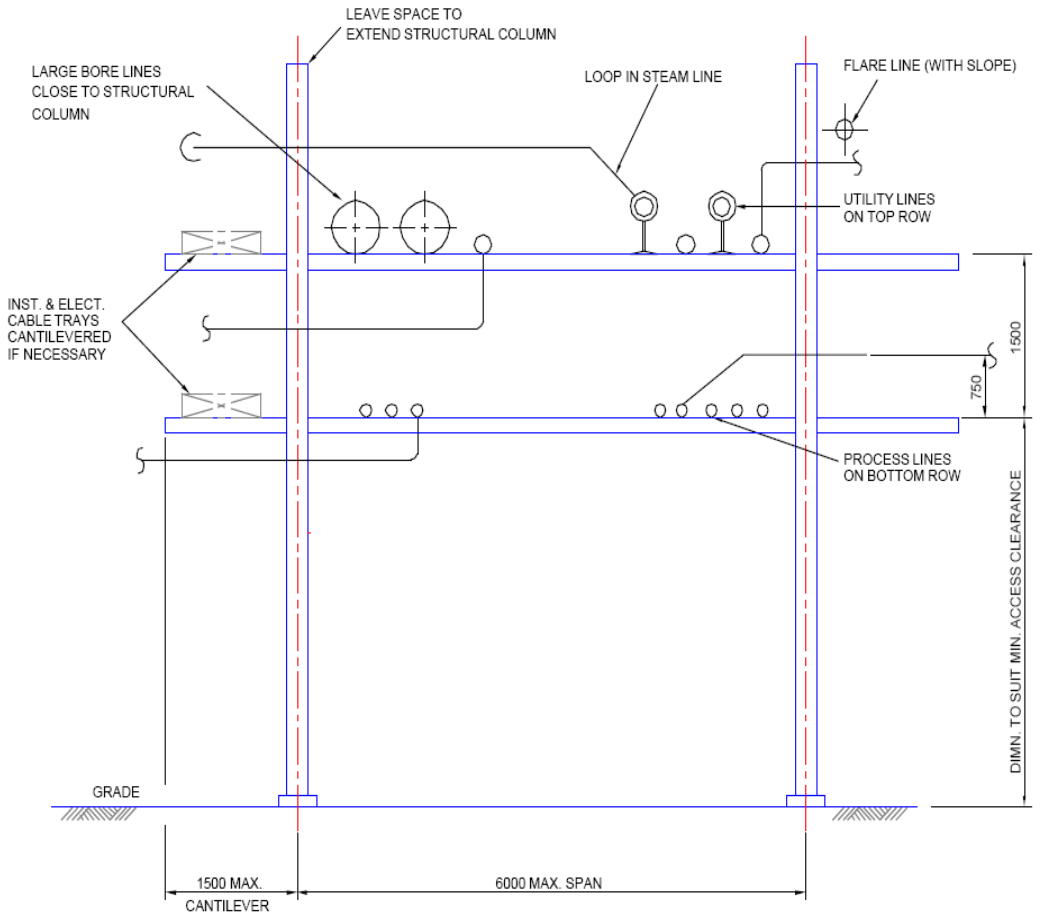
i. process lines,
ii. relief-line headers
iii. utility headers.
iv. Instrument & cable tray

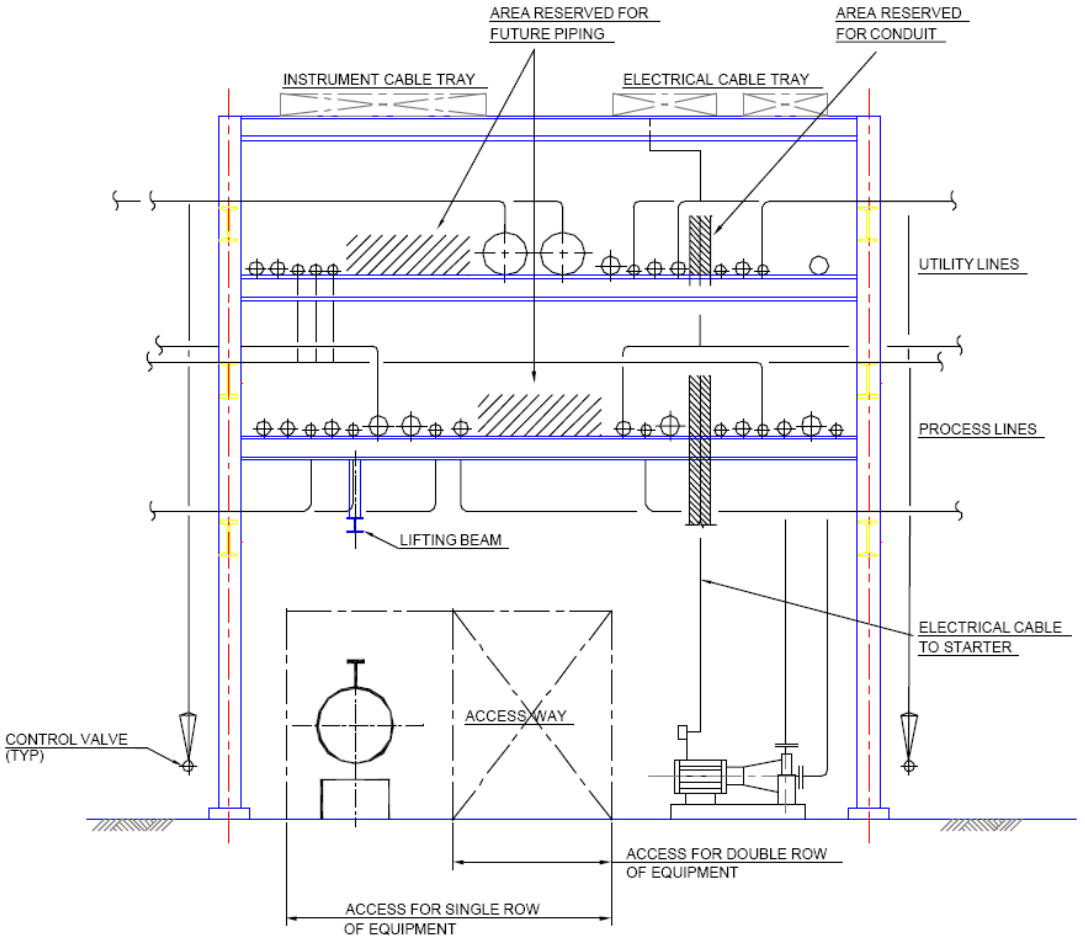
LINE LOCATION IN PIPE RACKS

- Largest & heaviest line to the outside.
- Usually utility lines at the top tier, process lines at the lower tier.
- Largest & hottest line at the rack edge.
- Group hot lines together that require expansion loops.
- Large bore cooling water lines at the bottom lines, as most users will be at grade level.
- Short distance process line will occupy lower level, longer distance the middle & top.
- Those process lines which interconnect equipment on the same side of the rack should be near the edges of the rack.
- Lines which interconnect equipment located on both sides of the yard can be placed either side of the yard.
- Line to be positioned according to approved line spacing chart
- Cable trays to be located on top level of pipe rack & isolated from dense pipe routing.

A general sequence of lines is also shown on the sketch below


Heavy lines (cooling water, process)
Process lines
Utility lines
Process lines
Heavy lines (cooling water, blowdown)
Fuel oil, chemical lines
Air, gas, service lines
Steam, condensate lines
Steam
Instrument Duct

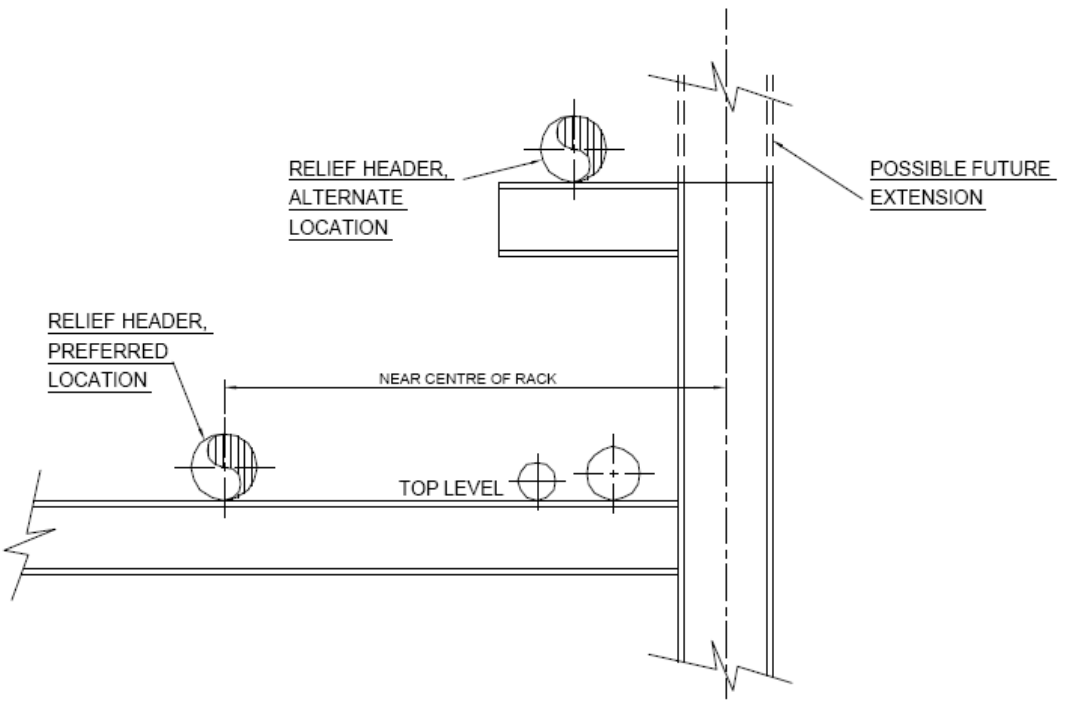

LEAVE SPACE TO
EXTEND STRUCTURAL COLUMN
LARGE BORE LINES
CLOSE TO STRUCTURAL
COLUMN
LOOP IN STEAM LINE
FLARE LINE (WITH SLOPE)
UTILITY LINES
ON TOP ROW
INST. & ELECT.
CABLE TRAYS
CANTILEVERED
IF NECESSARY
1500
750
PROCESS LINES
ON BOTTOM ROW
DIMN. TO SUIT MIN. ACCESS CLEARANCE
GRADE
1500 MAX.
CANTILEVER
6000 MAX. SPAN


AREA RESERVED FOR FUTURE PIPING
AREA RESERVED FOR CONDUIT
INSTRUMENT CABLE TRAY
ELECTRICAL CABLE TRAY
UTILITY LINES
PROCESS LINES
LIFTING BEAM
ELECTRICAL CABLE TO STARTER
ACCESSWAY
CONTROL VALVE (TYP)
ACCESS FOR DOUBLE ROW OF EQUIPMENT
ACCESS FOR SINGLE ROW OF EQUIPMENT

FLARE HEADER

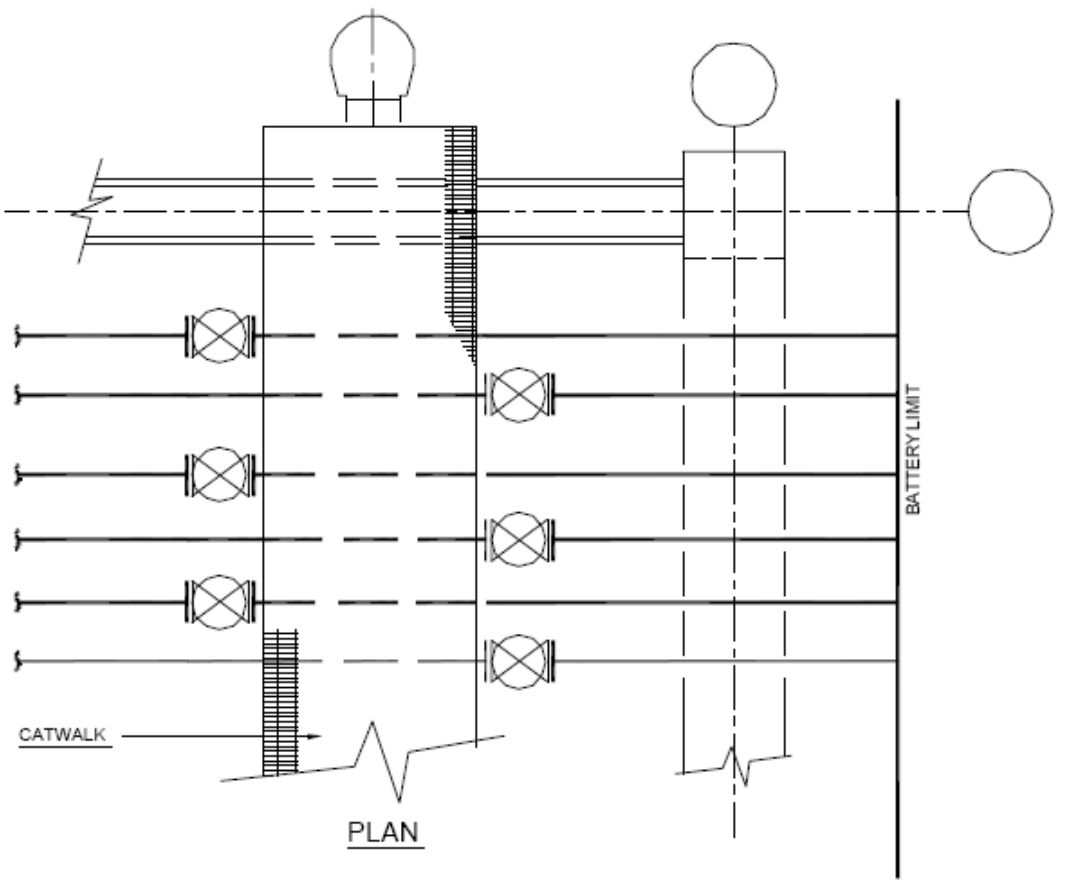
Following special consideration must be given to Flare Header Line.

- Flare line must not be pocketed.
- It must be sloped 1:200 in the direction of knock-out drum.
- It must be located at the edge of rack to accommodate any flat expansion loop required.
- It should be run at a height such that the safety valve can be kept as low as possible for access but still with sufficient elevation for it to self-drain into knock-out drum.
- Connection into header can be at laterally at 45° if pressure drop is critical.



FLARE HEADER

- Line crossing the battery limits will normally be valve & blinded & will consequently require access.
- Valve will be staggered either side of walkway to provide maximum clearance & be provided with extension spindles to hand wheels are required.
- Where lines are to cross battery limit at grade, valve will be brought down for access.



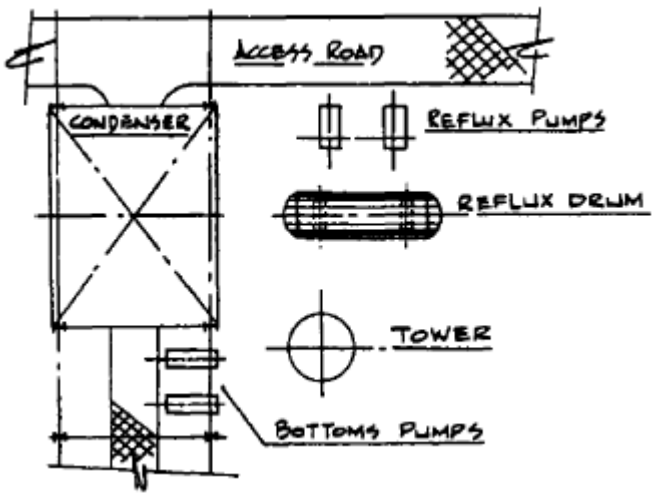
PIPING STUDY
DRUM PIPING

INTRODUCTION

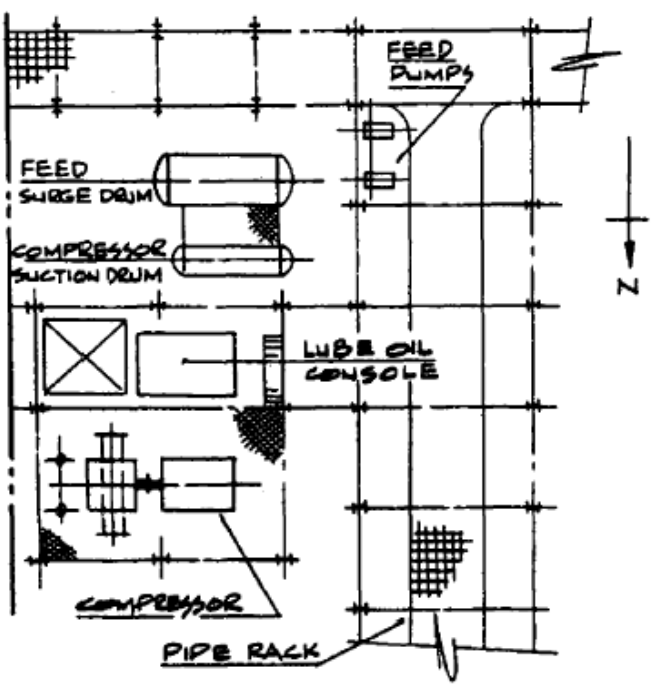
Drums are cylindrical hollow steel vessels used for general storage of liquids & chemicals, refluxing ,surge, steam generation, deaeration of boiler feed water etc.
Drums can be either horizontally or vertically mounted.

LOCATION

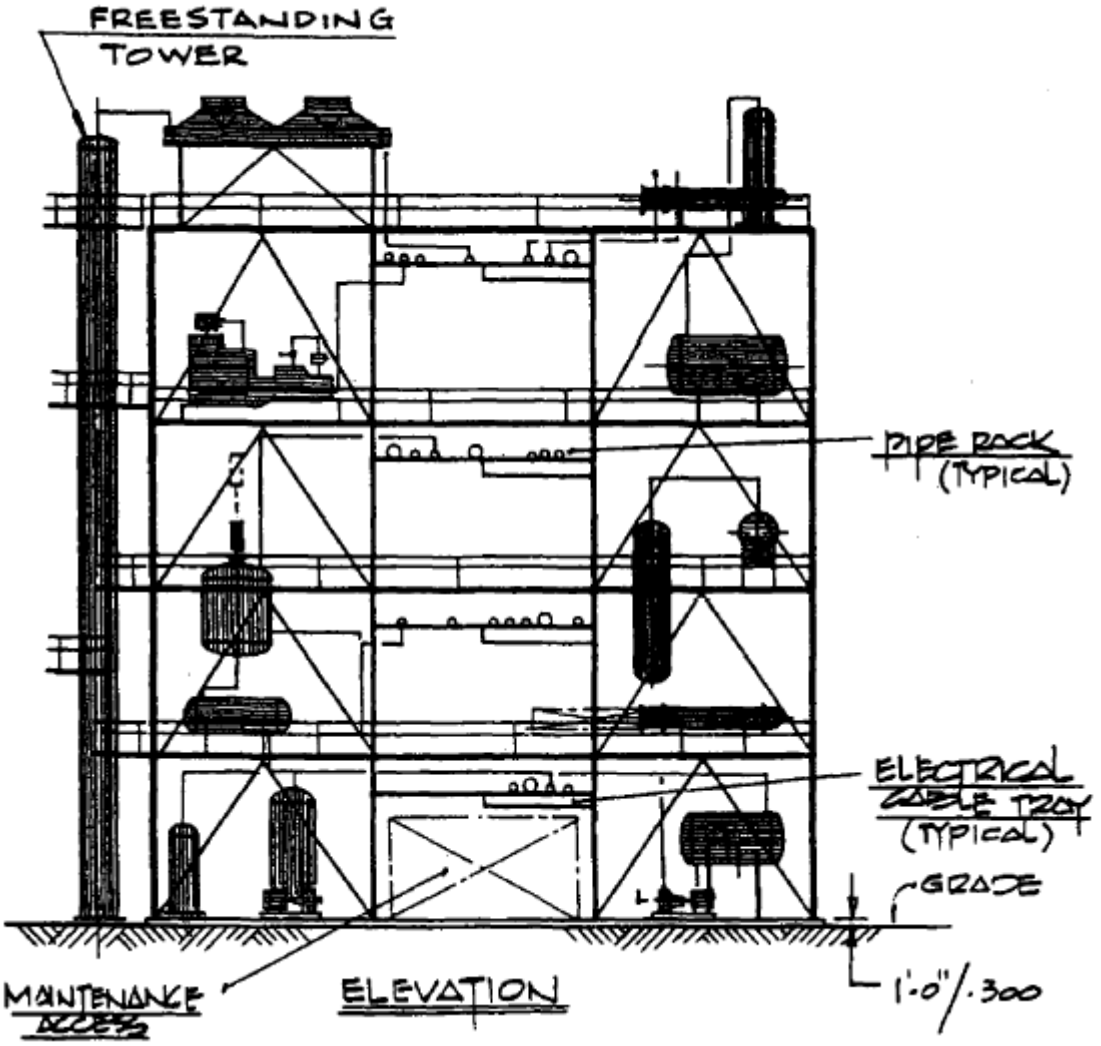
In a chemical process plant drums are generally placed on either side of pipe rack & adjacent to the related equipments to facilitate economic & simple piping interconnection between them. Location of few types of drums are illustrated in the fig below.



TYPICAL LOCATION OF REFLUX DRUM.



TYPICAL LOCATION OF SURGE DRUM & COMPRESSOR SUCTION DRUM.



TYPICAL DRUM LOCATION IN AN INDOOR PLANT

ESTABLISHING ELEVATION

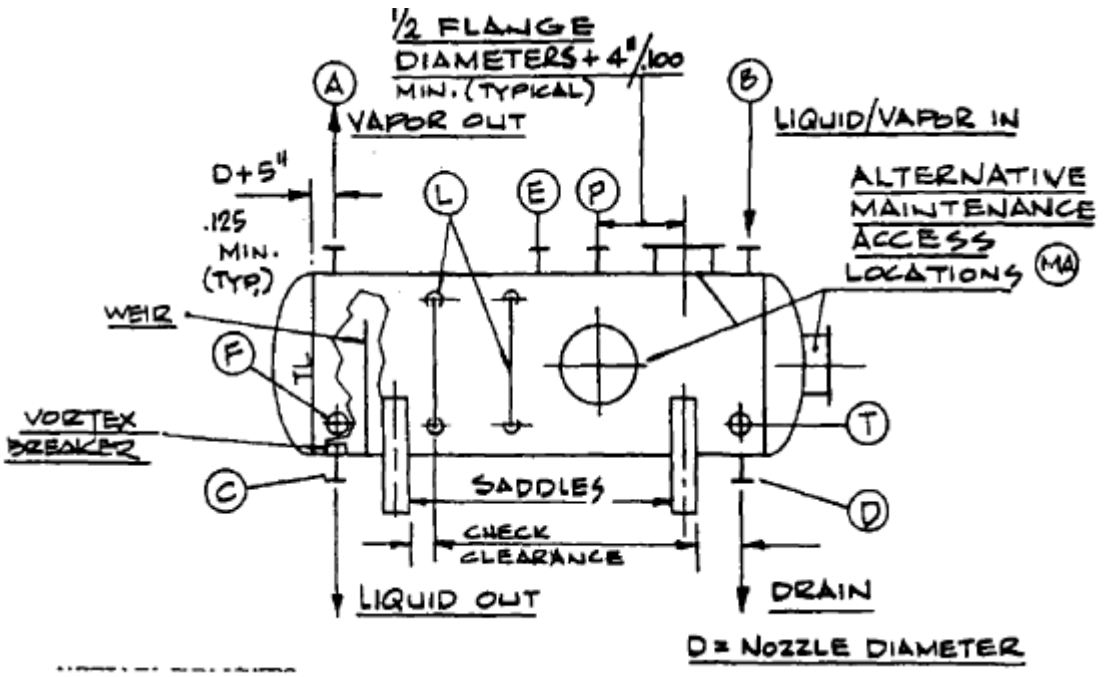
Drum elevation is dictated by following factors

- NPSH requirement of the pumps.
- Maintenance & operation asses.
- Common platform.
- Minimum clearance requirement
- Chemical storage drums are generally located underground.

SUPPORT

- Large vertical drums are supported by skirts.
- Small vertical drums can be supported by legs
- Elevated drums on structure are supported by lugs.
- Horizontal drums are usually supported by saddle.

NOZZLE LOCATION



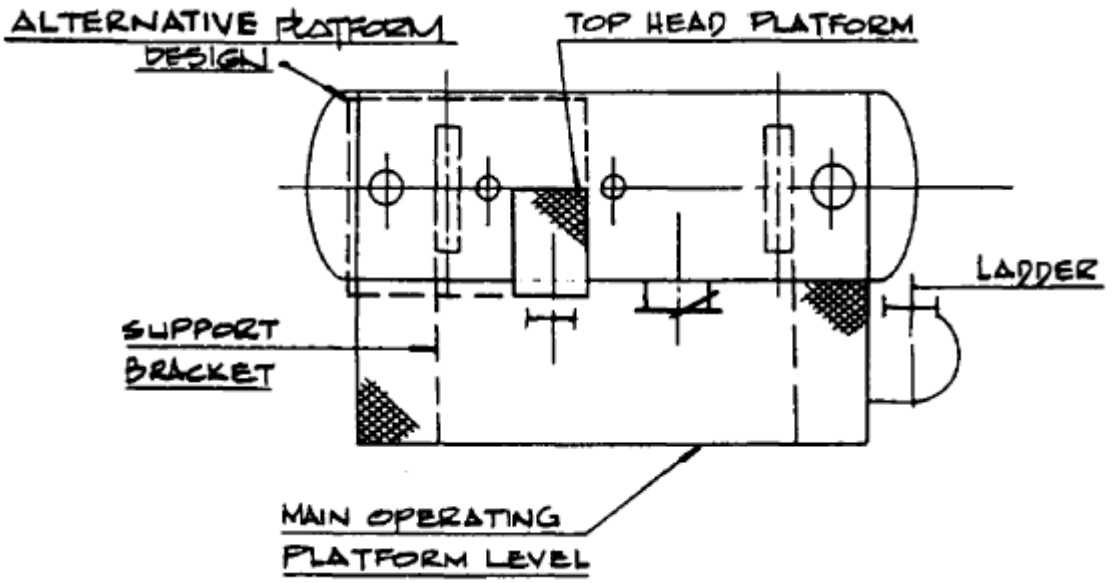
A - vapor out
B - Liquid in
C - Liquid out
D - Drain
E - Vent
F – Steam out
MA – Maintenance access
L - Level
P - Pressure
T - Temperature

PREFERED NOZZLE LOCATION FOR HORIZONTAL DRUM

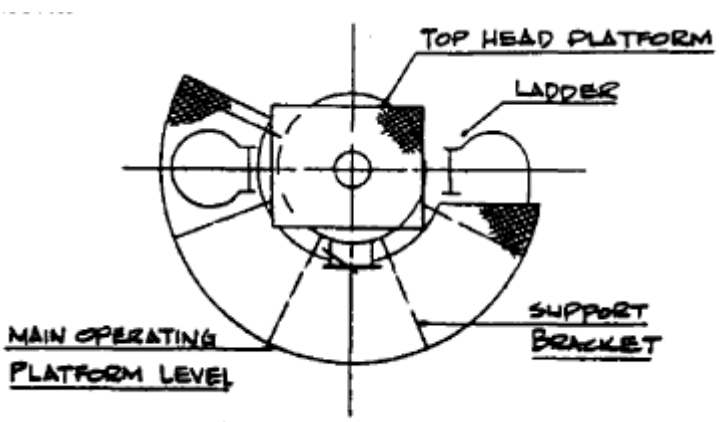
PLATFORM ARRANGEMENT

Platforms are generally requied at drums for the operation & maintenance access. For e.g. operating valves & instrument.

Some example of typical drum platform arrangement are shown in the fig below

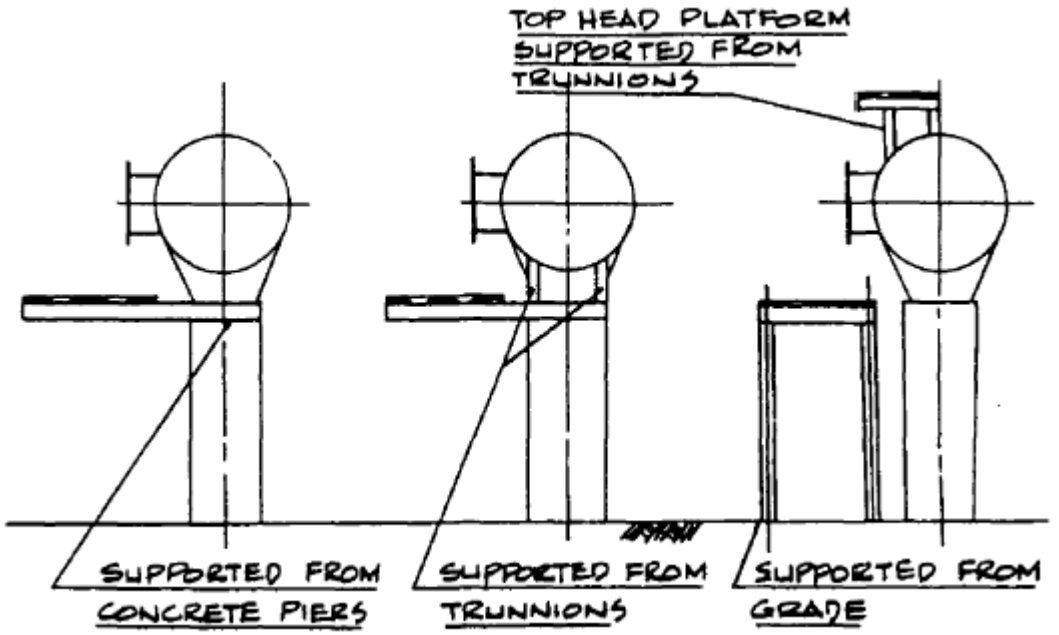


PLATFORM ARRANGEMENT AT HORIZONTAL DUM

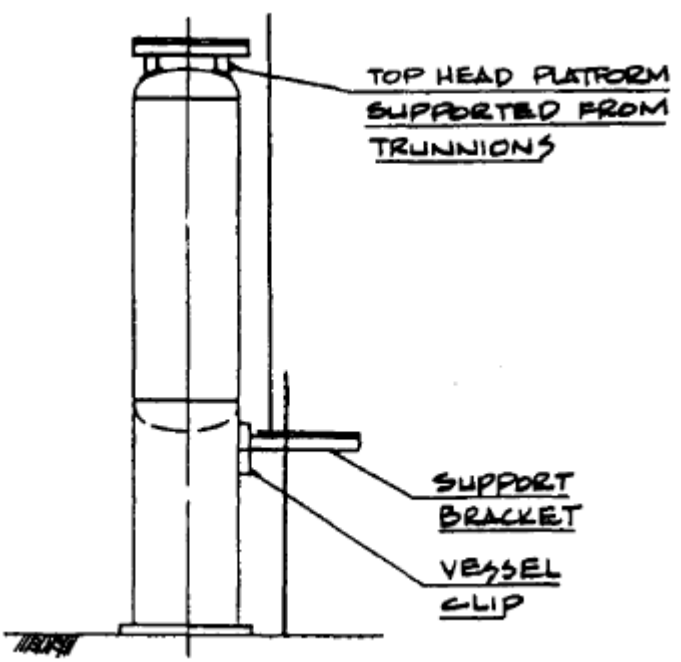


PLATFORM ARRANGEMENT AT HORIZONTAL DRUM

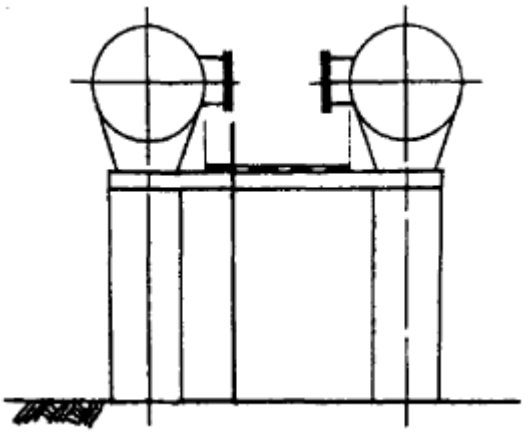
The fig below shows different ways of supporting the platform.



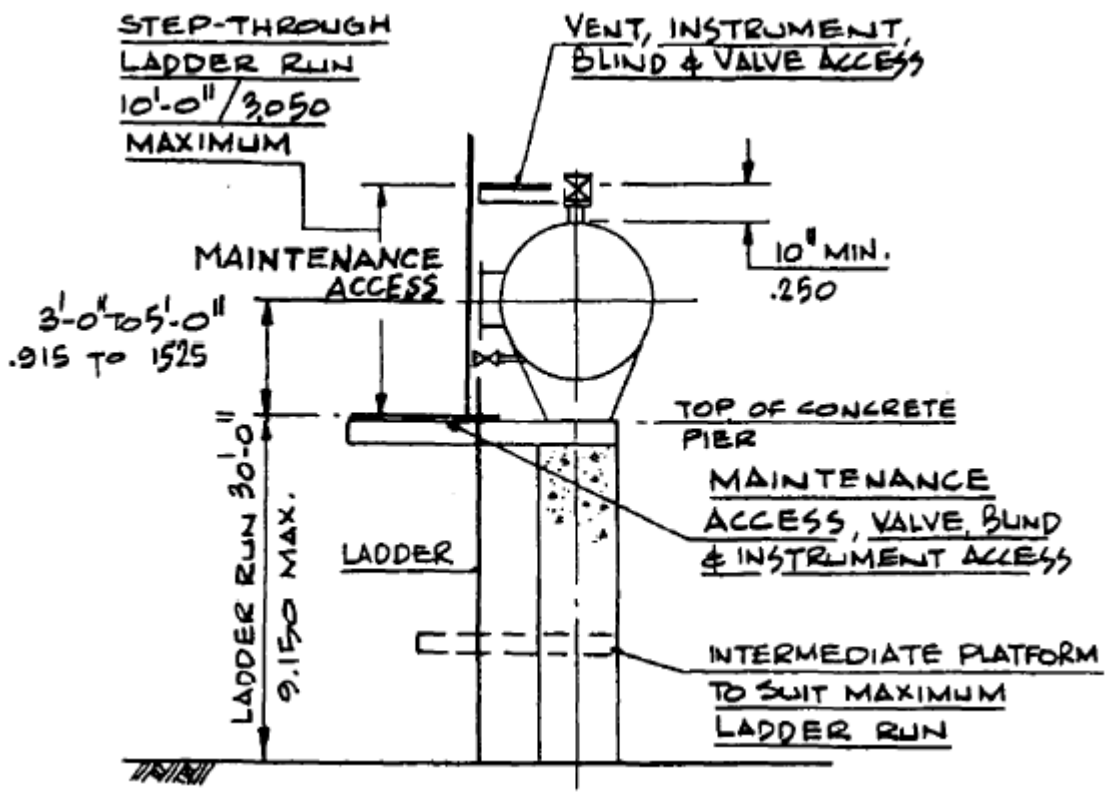
HORIZONTAL DRUM PLATFORM SUPPORT



VERTICAL DRUM PLATFORM SUPPORT.



COMMON PLATFORM ARRANGEMENT

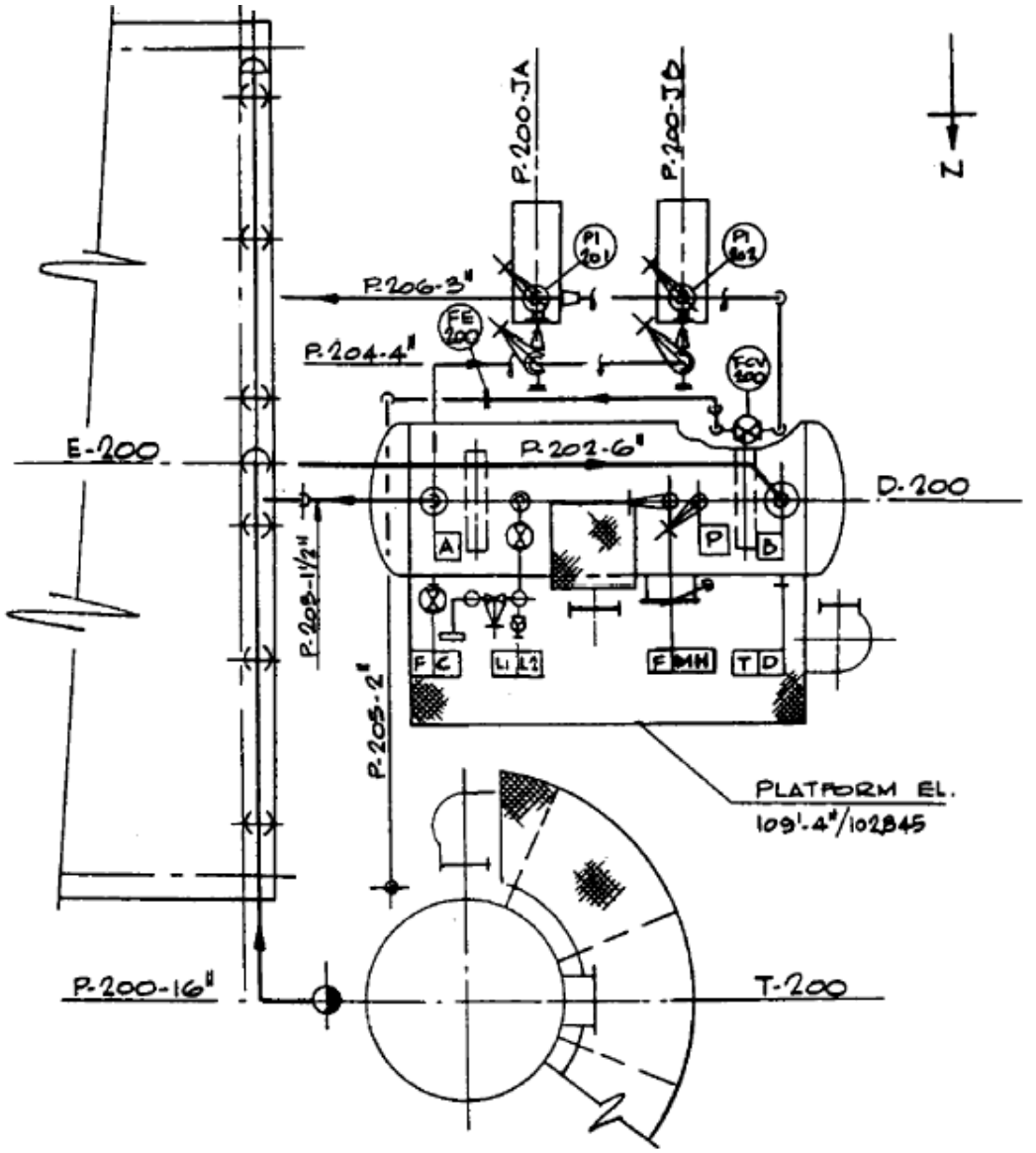


HORIZONTAL DRUM PLATFORM & LADDER ELEVATION REQUIREMENT

PIPING ARRANGEMENT

Following point must be considered while doing drum piping

- Elevation of lower platform to be established for instrument & manhole access.
- Elevation of top platform must be 150mm below the face of all flange served from this platform.
- Pump suction line to be run above minimum head clearance.
- If drum centerline elevation exceed 3m then platform is required at the manhole.
- Run piping at common BOP for the simplicity of supporting.
- Relief valve discharge to be high enough to allow line to enter top of flare header. If relief valve is not accessible from top of the platform, it must be relocated on the nearest platform with sufficient elevation. if relief valve is located away from the vessel, the line must be checked for correct sizing.



TYPICAL DRUM PIPING ARRANGEMENT

PIPING STUDY
PUMP PIPING

DEFINATION

Pump is defined as a machine used to generate a pressure differential in order to propel liquid through a piping system from one location to another.

COMMON PUMP TERMINOLOGY

Allowable Nozzle Loading:- Maximum stress that the piping configuration may impose on the pump suction & discharge nozzles.

Required Net Positive suction head:- Measure of the pressure drop of the liquid as it moves from the inlet of the pump to the eye of the impeller. It is expressed in " feet of Water"

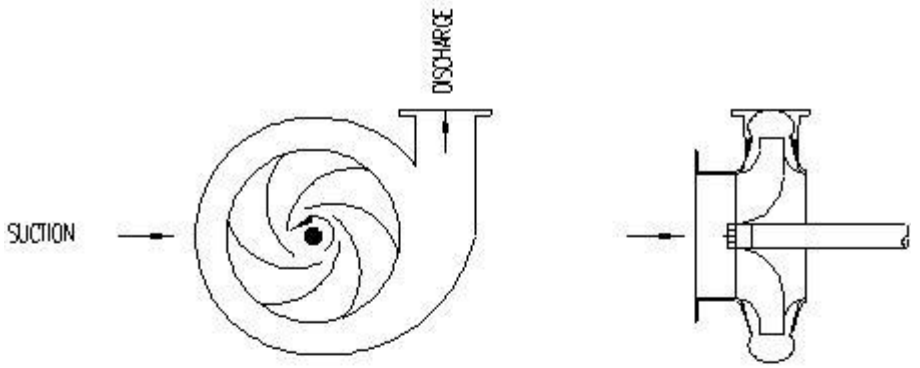
Available Net Positive suction head:- it is the net pressure available in a given system.
= (Vessel pressure + static head) – (liquid vapor pressure + functional losses)

Cavitations:- The rapid collapse of vapor bubbles on the impeller of pumps that results in the loss of head & capacity.

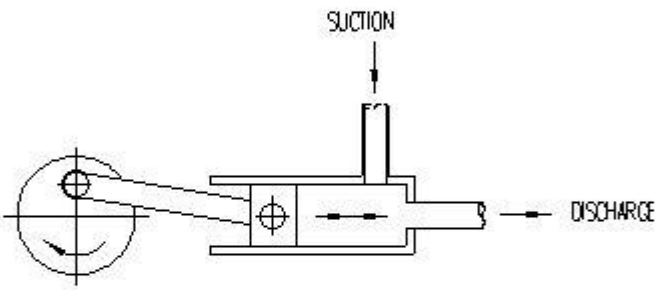
TYPES OF PUMPS

The three basic types of pump are centrifugal, reciprocating, and rotary.

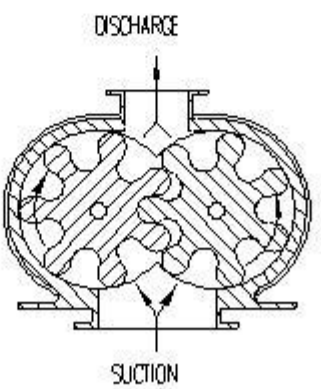
Centrifugal pumps :-are the most common. They are more economic in service and require less maintenance than other types. Rotation of the impeller blades produces a reduction in pressure at the center of the impeller. This causes liquid to flow onto the impeller from the suction nozzle thrown outwards along the blades by centrifugal force leaving the blade tips via the pump volute finally leaving the discharge nozzle, in a smooth, non-pulsating flow.
Some common types of centrifugal pumps are shown in the fig below



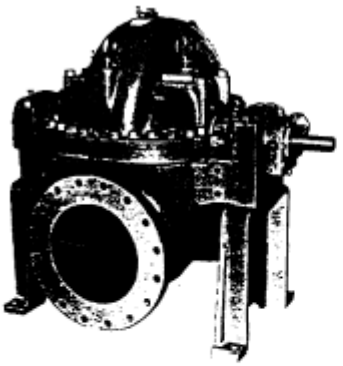
SIMPLE CENTRIFUGAL PUMP



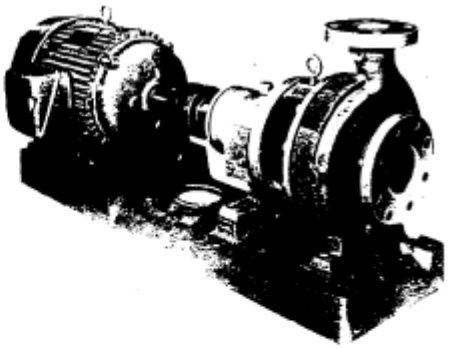
RECIPROCATING PUMP



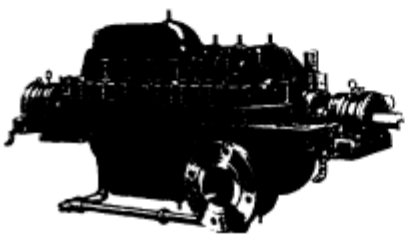
GEAR-TYPE ROTARY PUMP
HAVING TWO IMPELLERS



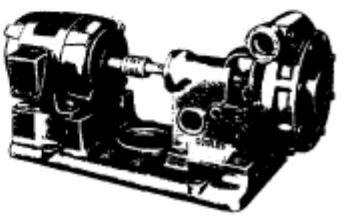
a. Horizontal Split-Case, Double Suction Pump



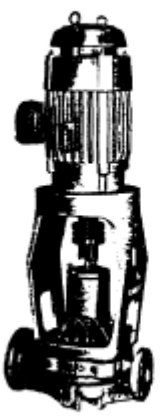
b. Chemical Process Pump (ANSI)
(for chemical and corrosive liquids)



c. Multistage, High-Pressure Pump



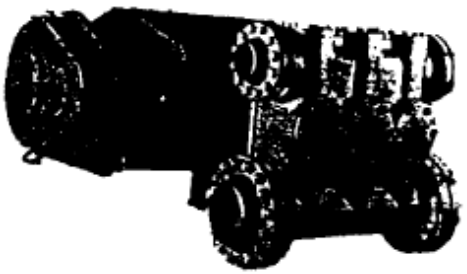
d. Horizontal Frame-Mounted Pump



e. Inline Process Pump

f. Vertical Sump Pump

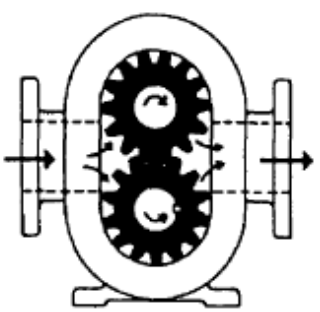
Reciprocating pumps:- is used where a precise amount of liquid is required to be delivered, also where the delivery pressure required is higher than can be achieved with other types. The liquid is moved by means of a piston in a cylinder after being drawn into the cylinder,



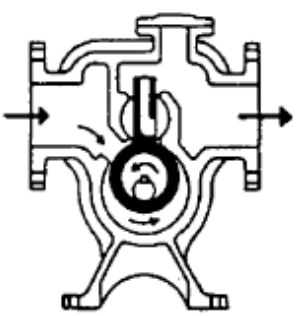
a. Single-Acting Plunger Pump (for very high pressure with moderate flows and high efficiency)

b. Double-Acting Piston Pump (for viscous liquids and slurry service)

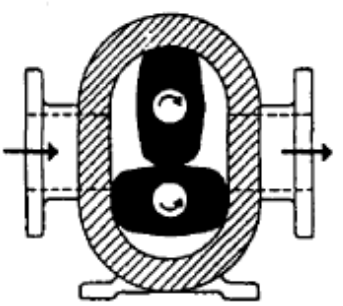
Rotary pumps:- are used to move heavy or very viscous fluids. These employ mechanical means such as gear, cam and screw, to move the fluid.



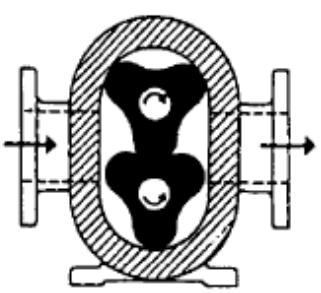
a. External-Gear Pump



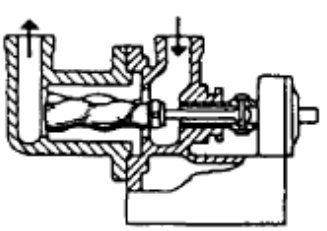
b. Cam and Piston



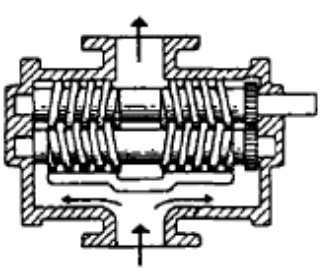
c. Two-Lobe Pump



d. Three-Lobe Pump



e. Single-Screw Pump



f. Two-Screw Pump

LOCATION

- The primary goal is to minimize the length of suction piping while satisfying the piping flexibility requirement as well as allowable loads that may be subjected to the nozzle.

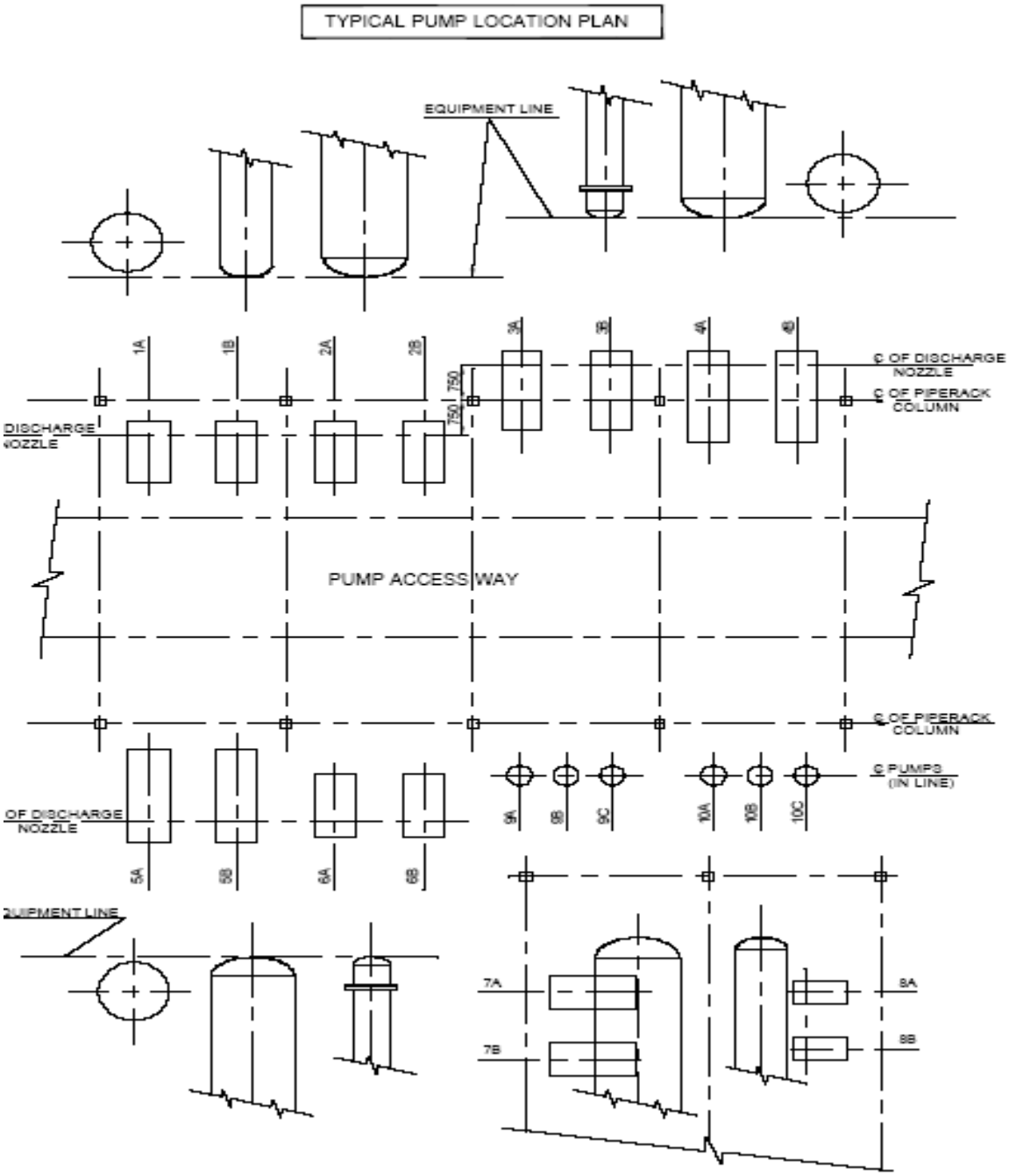
- Common location of pumps in chemical and petrochemical plant is under the pipe rack at grade. Pumps are to be placed close to and below the vessels from which they take their suction in order to have net-positive suction head (NPSH) required by the pump.

- Any reduction in suction line size required at pumps should be made with eccentric reducers, with flat side up to avoid accumulation of vapor pocket. Changes in direction of suction lines should be at least 600mm away from the pump suction.

- Pumps should be arranged in line with drivers facing the access gangway. Clearances and piping should provide free access to one side of the driver and pump. There must be good access to gland / seal and coupling where most of the maintenance and adjustments are done.

- With normal pipe rack column spacing of 6m, it is generally found that only two pumps of average size can be arranged between the columns, with a preferred clearance of 1m between the pumps. The clearance between any structure / steel work and the pump discharge line shall be 0.75m minimum. For small pumps upto 18 KW, clearance between pumps should be 0.9m minimum. A space of 2 - 2.5 m should be provided for working aisle.

- 2.5 Means of lifting should be provided for pumps or motor weighing more than 25Kg.



i. Pumps 1A,1B,2A,2B are located under the main pipe rack when there is minimum chances of hydro-carbon leakage to the electric motor.

ii. Pumps 3A,3B,4A,4B partially located under pipe rack with casing set outside the column line .the discharge line can rise into the vertical slot that is usually provided for line entering or leaving the pipe rack.

iii. Pumps 5A,5B,6A,6B are located outside the pipe rack when hydrocarbon spills are more likely.

iv. Pumps 7A,7B,8A,8B are located directly under the process equipment that they serve .which is supported in the structure above

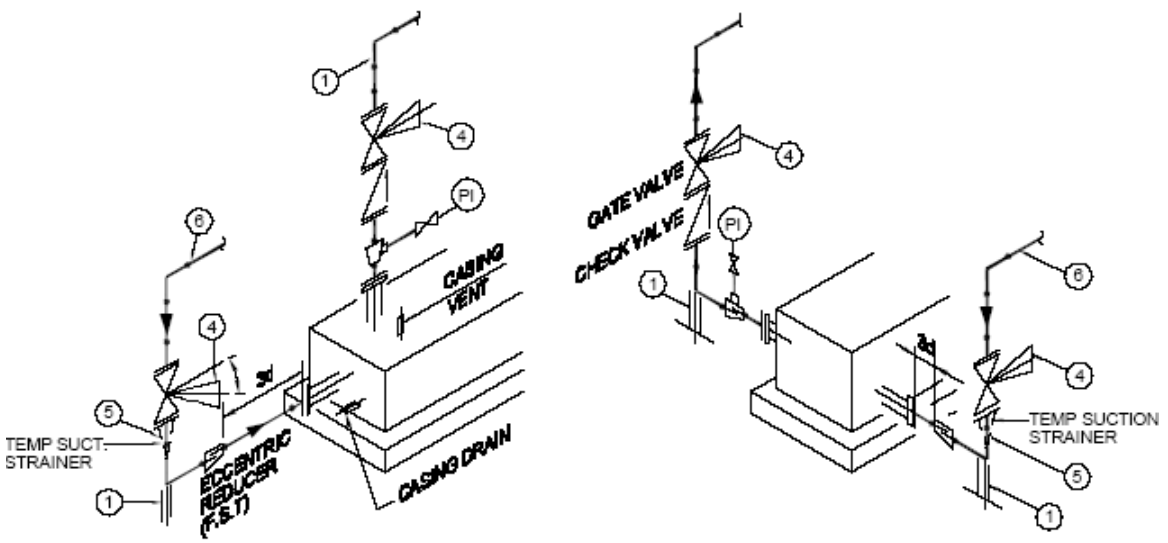
v. Pumps 9A,B & C & 10A,B & C are in line , basically treated as piping system.

PUMP PIPING

- Pump suction piping shall be as short as possible and shall be arranged so that vapor pockets are avoided.

- Reducers immediately connected to the pump suction shall be eccentric type flat side up to avoid accumulation of gas pocket.

TYPICAL PUMP SUCTION AND DISCHARGE PIPING

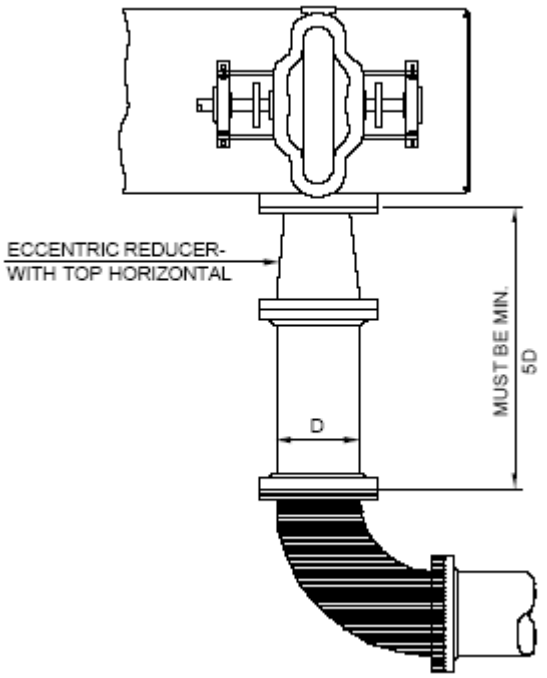


END SUCTION -TOP DISCHARGE
(BASIC INSTALLATION)

SIDE SUCTION - SIDE DISCHARGE
(BASIC INSTALLATION)

- For end suction pumps, reducer shall not be directly connected to the suction flange. A straight piece 3 times the line size shall have to be provided at the suction nozzle.

- For top suction, pump elbow shall not be directly connected to suction flange. A straight piece of minimum 5 times the nozzle size shall have to be provided at the suction nozzle.



- T-type strainers are to be used for permanent as well as temporary to avoid disassembly of suction piping for strainer cleaning.

- Piping shall be so arranged that forces and moments imposed on the pump nozzles do not exceed the allowable values specified by the vendor.

- When a suction vessel operates under vacuum the vent connection of the pump has to be permanently connected to vapor space of the suction vessel to allow possible filling of the pump with liquid before it is started.

- For pumps handling hot fluid, the first factor concerns the support of pump piping, which often includes large expansion loops for flexibility. When the pumps are located below the pipe rack (to reduce possibility of hydrogen leakage over motor), support becomes easy otherwise the designer should consult stress engineer for best location of stops and hanger. With the optimum layout and support, it is to be ensured that the loadings on the pump nozzles are not exceeded beyond the allowable limits.

- Piping configuration for a group of pumps of similar size shall follow identical pattern and the stress analysis of one pump piping should be applicable to the other pumps.

- Auxiliary Pump Piping Arrangements:

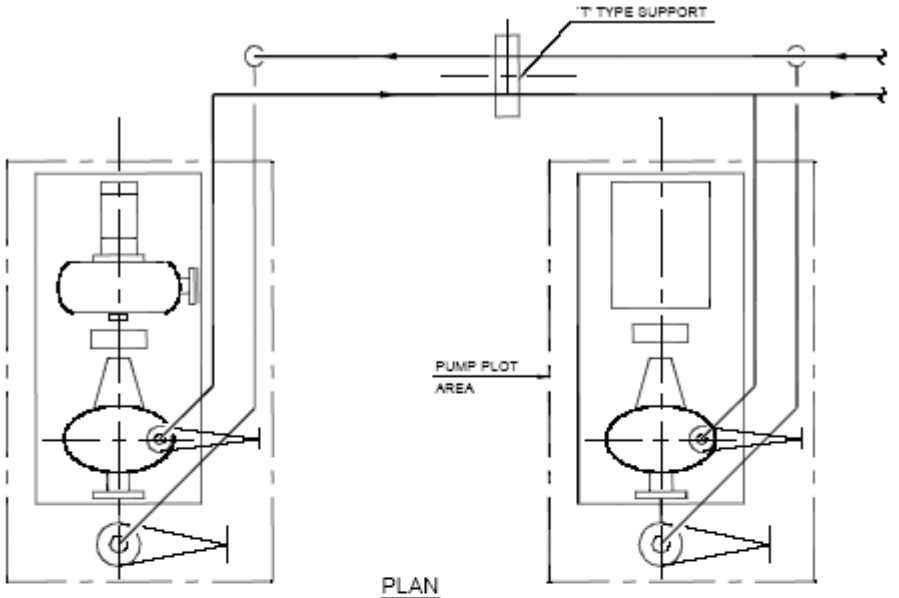
- ✓ The auxiliary piping are usually cooling water to mechanical seals, bearings, stuffing boxes, gland quench and lantern rring flush.

- ✓ When pump fluid is used, a line is attached to the vent connection on the pump case. The circulated seal fluid has to be sent back to pump stream or referred through the seal to pump internal clearances.

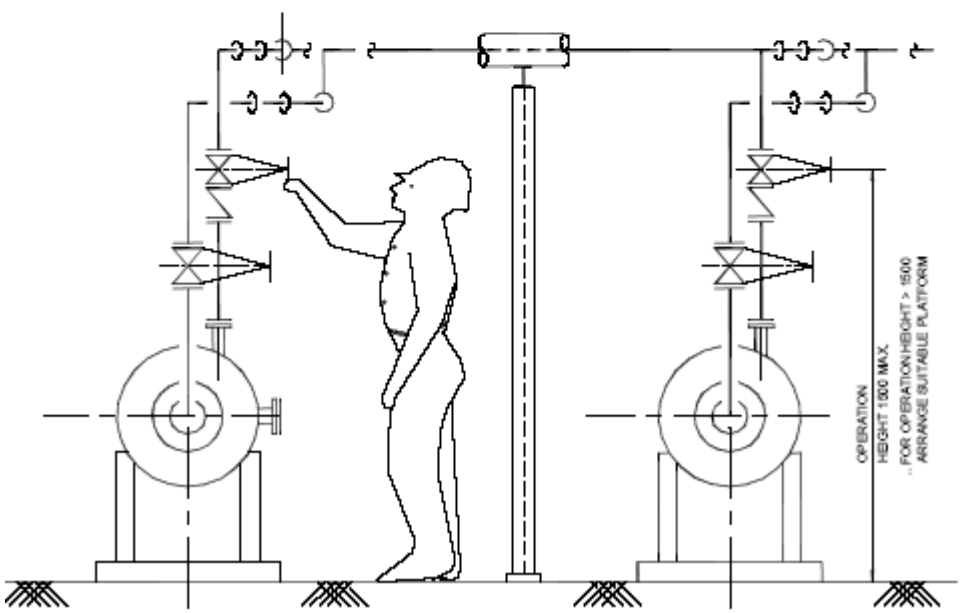
- ✓ In viscous or high temperature hydrocarbon liquids, the seal fluid medium circulates from external source through connections on the pump seal. Various auxiliaries piping plan is recommended in API 610 for proper selection according to design requirements.

- Pump vendors usually supply the auxiliary piping and the neat arrangements of these piping and its support are to be ensured by the designer while reviewing the vendor document.

- A typical arrangement for piping and valves operation is illustrated in Fig below with maintenance and operation access.

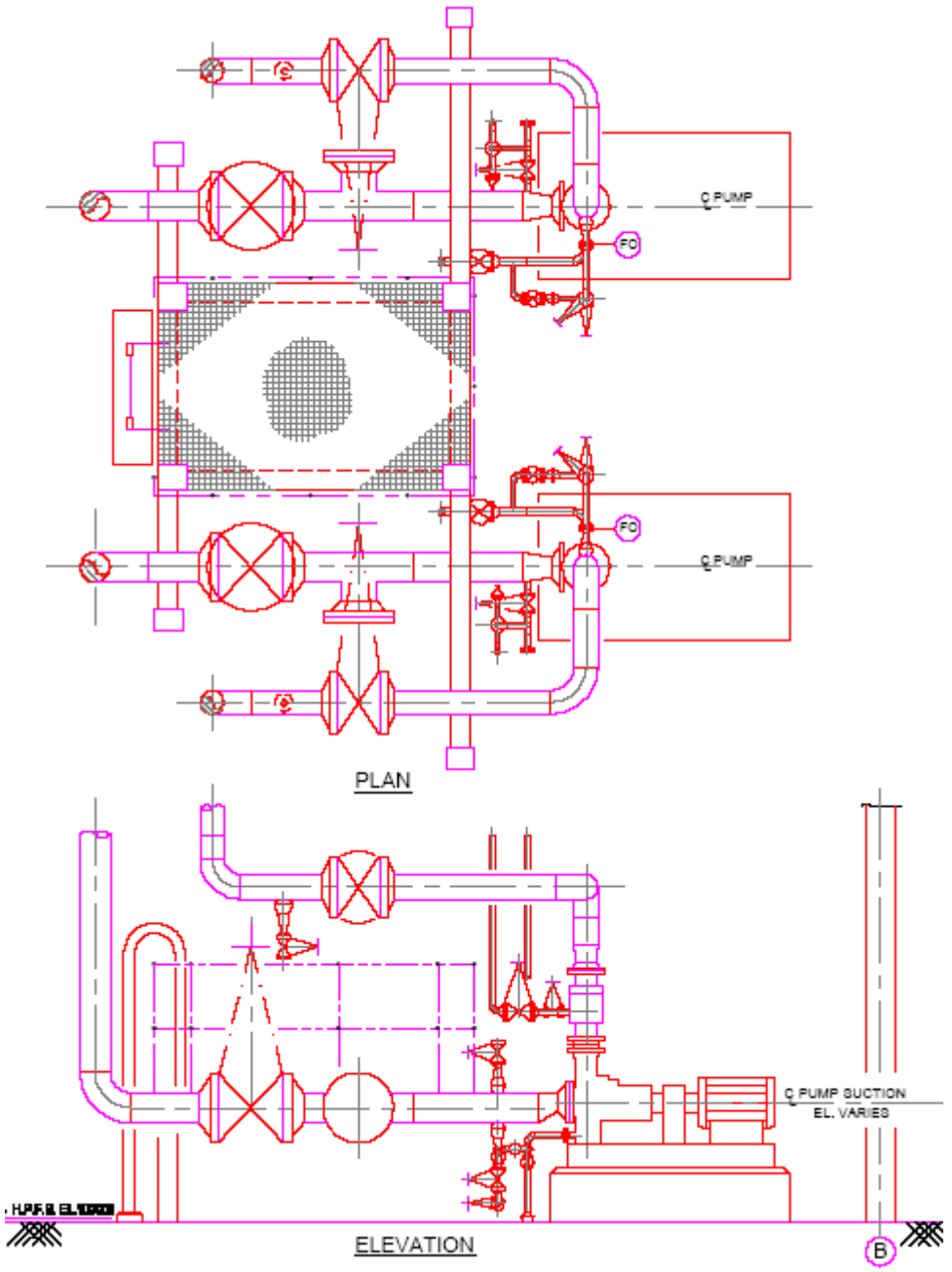


PLAN

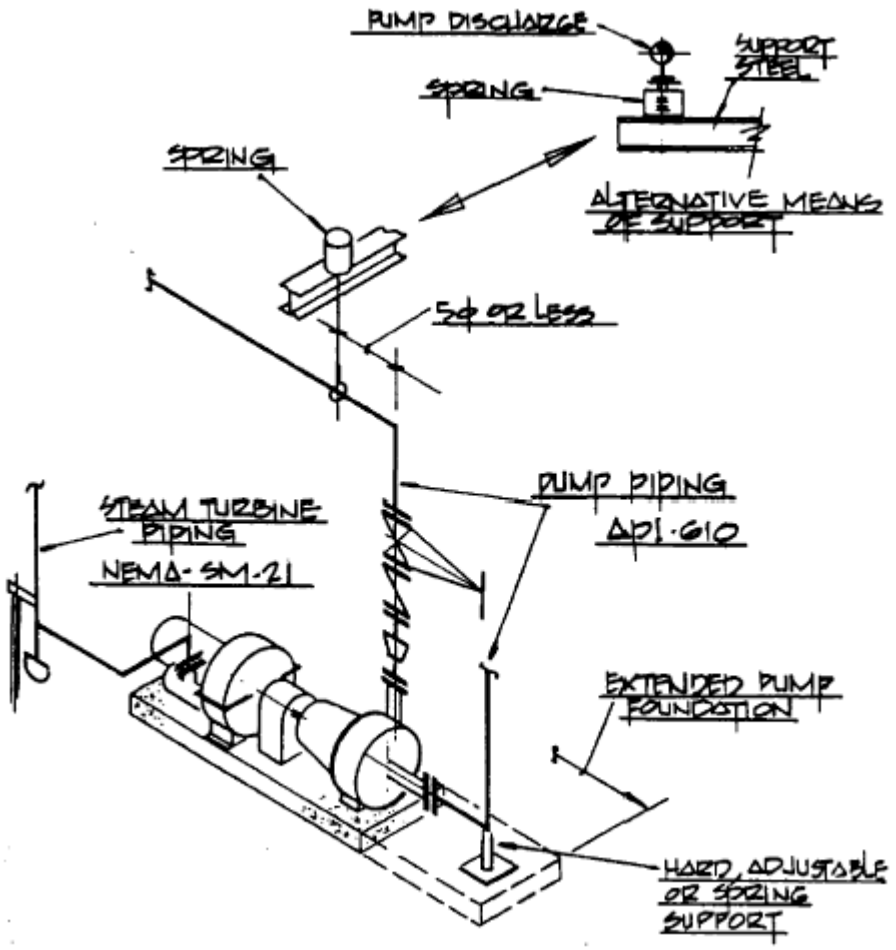


ELEVATION

- A typical suction and discharge piping arrangement with common platform for operation of valves connected to two adjacent pumps is illustrated in Fig below



PUMP PIPING SUPPORT



- Plant designer must have basic knowledge of stress & pipe support to generate a sound pump piping arrangement.
- Suction line is commonly supported under the elbow by pipe or steel member called as Dummy support.
- For high temperature pumps spring type support is used to support suction line.
- The discharge line should be supported close to top elbow, within 5D of the elbow.
- Discharge line can be supported in two ways. One is to sit the spring support on the steel with a rod hanger & clamp. Other method is to place base spring on the steel with discharge line resting directly on the load flange of the spring.
- Pump nozzle loadings falls under the API-610 code.

PIPING STUDY
COMPRESSOR PIPING

DEFINATION
Compressors are the mechanical means to increase vapor pressure, as pumps are used to increase liquid pressure .

TYPES OF COMPRESSOR
There are two basic types of compressors, reciprocating and centrifugal.

Reciprocating Compressor :- Reciprocating compression is the force converted to pressure by the movement of the piston in a cylinder. These machines are generally specified for lower volumes & high pressure . These machines are subjected to pulsation and therefore produce vibration effects.

Centrifugal Compressor:- Centrifugal compression is the force converted to pressure when a gas is ejected by an impeller at increasing velocity. Centrifugal compressors are specified for large quantities of vapor. Pressure differential may be small or large. These machines are not subject to pulsation and therefore do not produce vibration effects.

COMPRESSOR DRIVES
Drivers fall into three categories, i.e. electric, steam and gas.
Electrical drivers range from small flameproof motors to large motors, 2000 HP or more, requiring their own cooling systems. Steam drivers are comprised of single or multistage turbines, either fully condensing of backpressure. Gas drivers cover gas turbines or gas engines.

LAYOUT

General

- Compressors are normally located inside a permanent shelter or building (Compressor House) for weather protection. The compressor house can be fully covered by side cladding to grade level if handling non-hazardous materials e.g. air.
- For compressor, handling flammable materials, ventilation and weather protection is assured by significant openings upto 2.5m ht. at grade level together with roof ventilators.

- Except for lighter than air gases, trenches, pits and similar gas traps should be avoided within gas Compressor House. This will eliminate chances of suffocation or explosion risk due to accumulation of heavy gases in pits.

- For open compressor house, the side cladding on all sides should be provided upto 1m below crane level.

- The general arrangement of compressor house shall consider the vendor drawings and vendor recommendation, if any, for space and location of auxiliary units.

- For compressor house where a number of installations from multiple vendors are to be accomodated, a thorough discussion should be held among the engineers of Piping, Process and Civil discipline to finalize the detail plot plan of the unit.

- The clear space between compressors shall be minimum 1.5m or half width of the compressors.

- The clearance between rows of compressor and at the end of each compressor shall be also 1.5m.

- Built-in maintenance equipment viz. traveling gantry with overhead crane / monorail with hoist and chain-pulley blocks as well as the drop-out areas shall be provided in the compressor house.

- The clearance above the compressor should be at least 3m more than the longest internal part to be removed.
- The substantial space required for lube oil and seal oil consoles shall be taken into consideration to prepare unit plot plan.

Reciprocating Compressor

- Reciprocating compressor generates considerable vibrations due to unbalanced forces, pulsation etc. For this reason, the reciprocating compressors should be located as close as possible to the grade level.

- The building foundation and the compressor foundation should be separate to avoid transmission of vibrations from compressor to the building structure.

- The pulsation dampeners are used to eliminate pulsation in suction and discharge piping and to separate the source of vibration from the piping system.

- The piping arrangement around the reciprocating compressor should be planned at grade level for ease of supporting with minimum changes in direction

- The piping routed simply with short run is less prone to vibration, but at the same time the line should be checked for the flexibility and the compressor nozzle loadings within the allowable limits furnished by the vendor.

- The piping shall remain clear of the cylinders and the withdrawal space at cylinder heads.

Centrifugal Compressor

- The general considerations for centrifugal compressor layout are same as the reciprocating compressor, exception being that for centrifugal compressor, the pipeline size is larger, temperatures can often be higher and nozzle loadings on compressor casing are lower.

- The knockout pots, inter stage exchangers can be located at grade outside the compressor house with auxiliary equipment consisting of lubricating, seal and control oil systems be placed adjacent to the machine.

- The centrifugal compressor inside a building normally has foundations separate from the building foundation.

- The centrifugal compressor with drive is generally mounted on the concrete table supported on RCC column.

- The maintenance facilities like overhead crane or monorail at the center of the compressor bay and the drop-out area at one of the building or shed is the usual practice.

- If the building is having installation of several compressors, the height of the traveling crane is to be carefully estimated so the machine components and rotors can be lifted over the adjacent equipment.

- The compressor suction lines must be free of any foreign particles that could damage the internals of the machine. Strainers are installed in the inlet line between the isolation valve and the compressor inlet nozzle.

- ASME PTC code recommends a minimum 5 times diameter of straight run piping between elbow and the inlet nozzle.

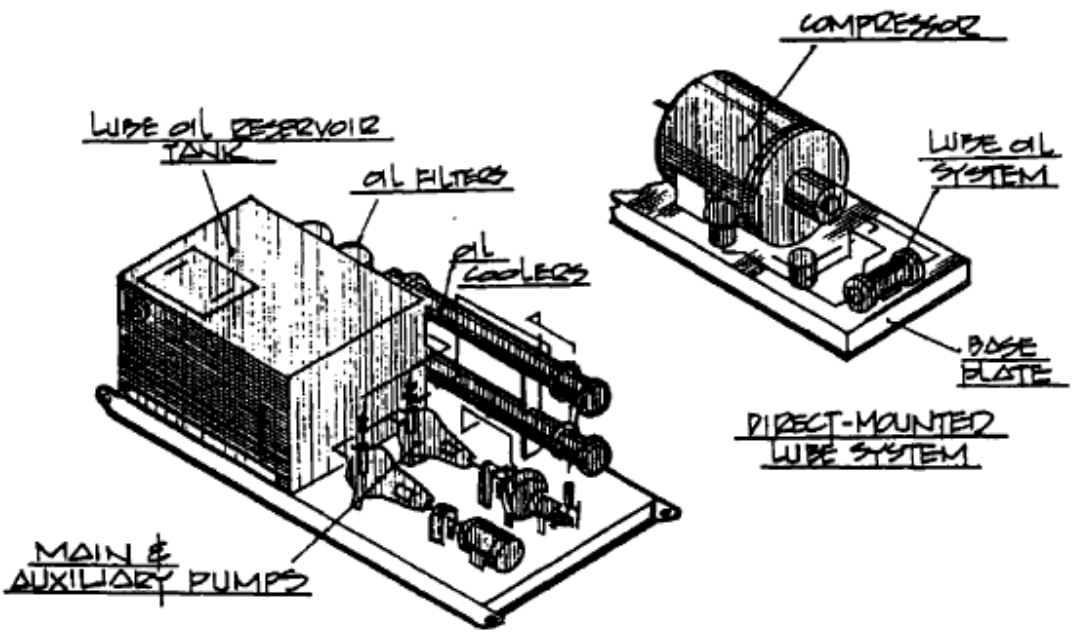
- The designer shall ensure that all connections shown on the vendor piping and instrumentation diagrams are properly taken care in the piping layout. All valves shall be arranged in such a way that they are accessible from the operating floor around the machine.

AUXILIARY EQUIPMENT

Centrifugal and reciprocating compressors and their drives require a variety of auxiliary equipment to support their operation. The equipment for these compressors is discussed below.

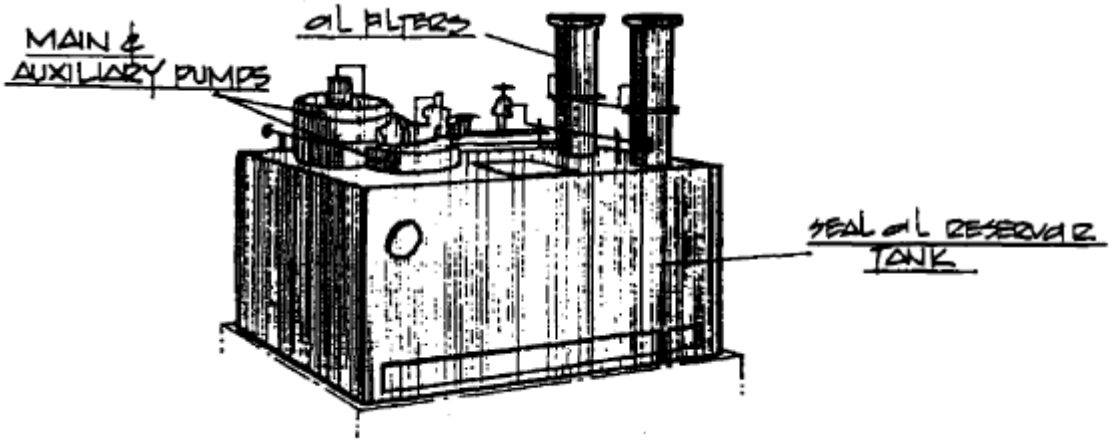
- ***Lube Oil Consoles :***

  Compressor bearings receive lubricating oil from the lube oil console. These consoles may be either stand-alone or be mounted directly onto the compressor frame. The console consists of lube oil reservoir, oil filters, oil coolers and lube oil pumps.



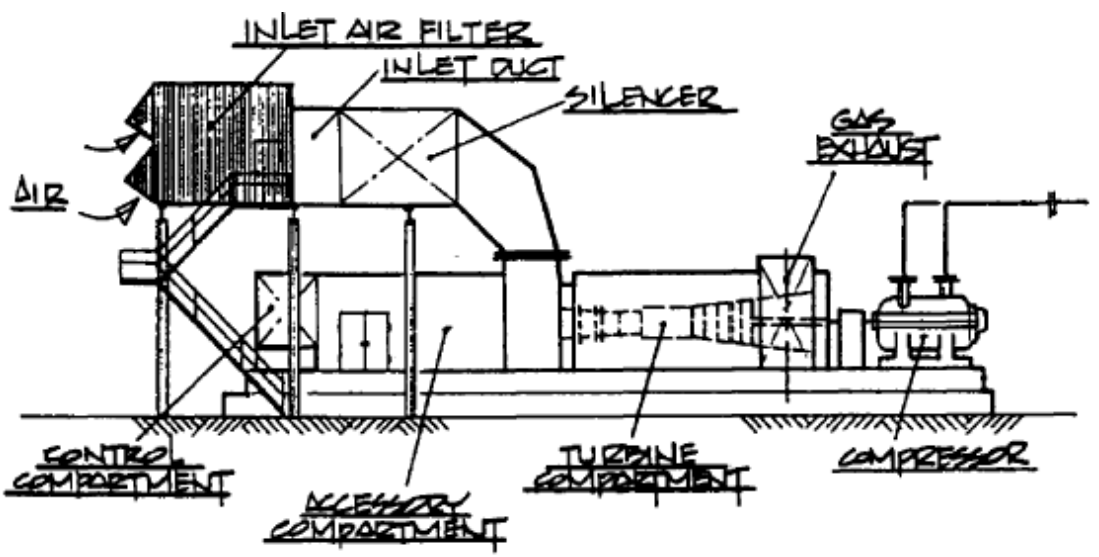
- ***Seal Oil Consoles :***

  The hydraulic seals located at the outer ends of the compressor shaft receive oil from the seal oil console. The seal oil console consists of seal oil reservoir, oil filters and main seal oil pumps.

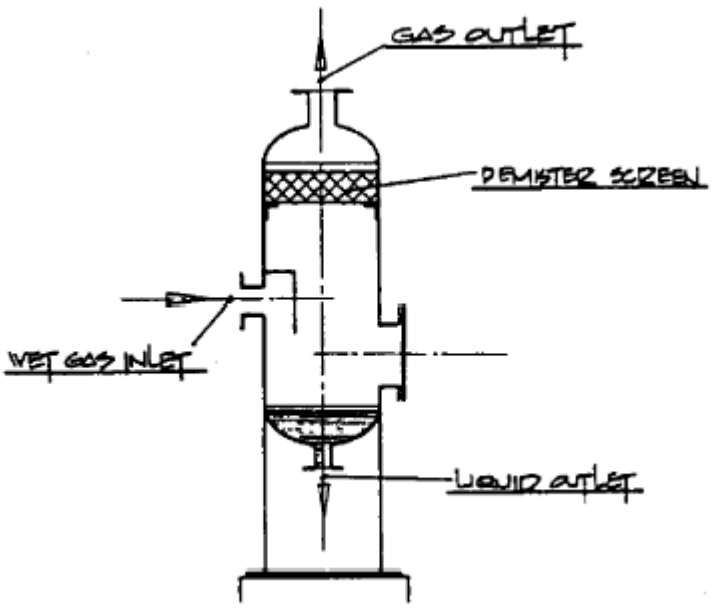


- ***Inlet Filters :***

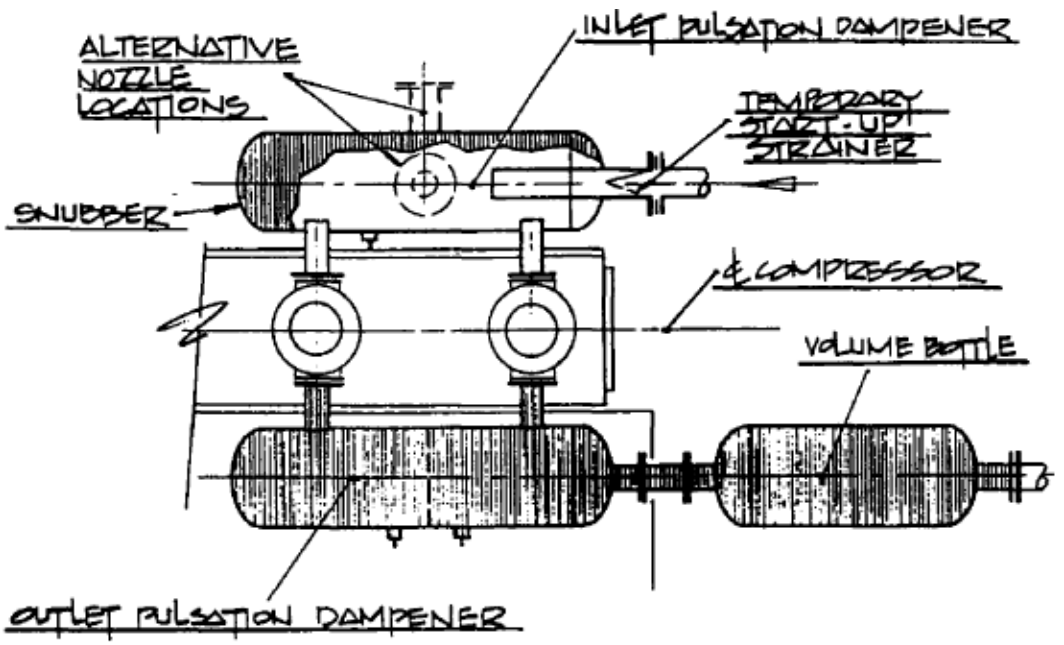
The inlet filters for air compressors are installed outside the building /shed at a level suitable for clean air suction without any obstruction in the airflow. The vendor drawing of the filter shall be reviewed for correct inlet/outlet ducting and the supporting arrangement.



- ***Suction drum / knockout pot :***
  As compressors require dry gas free of foreign particles, it is necessary to pass inlet gas through the suction drum or knockout pot. This vessel removes moisture and particles from the gas by passing it through a demister screen located just below the outlet nozzle. A typical knockout pot is illustrated in Fig.below



- ***Pulsation dampener / volume bottles :***
  The negative effects of vibration on the life of reciprocating compressors and associated piping can be minimized by the use of pulsation dampeners. The pulsation dampeners are sized by the compressor vendor and are mounted directly on the cylinder nozzles. Volume bottles are used to reduce vibration. They are located downstream of the discharge pulsation dampener and are similar to snubbers without internal baffles or choke tubes.



PIPING ARRANGEMENT

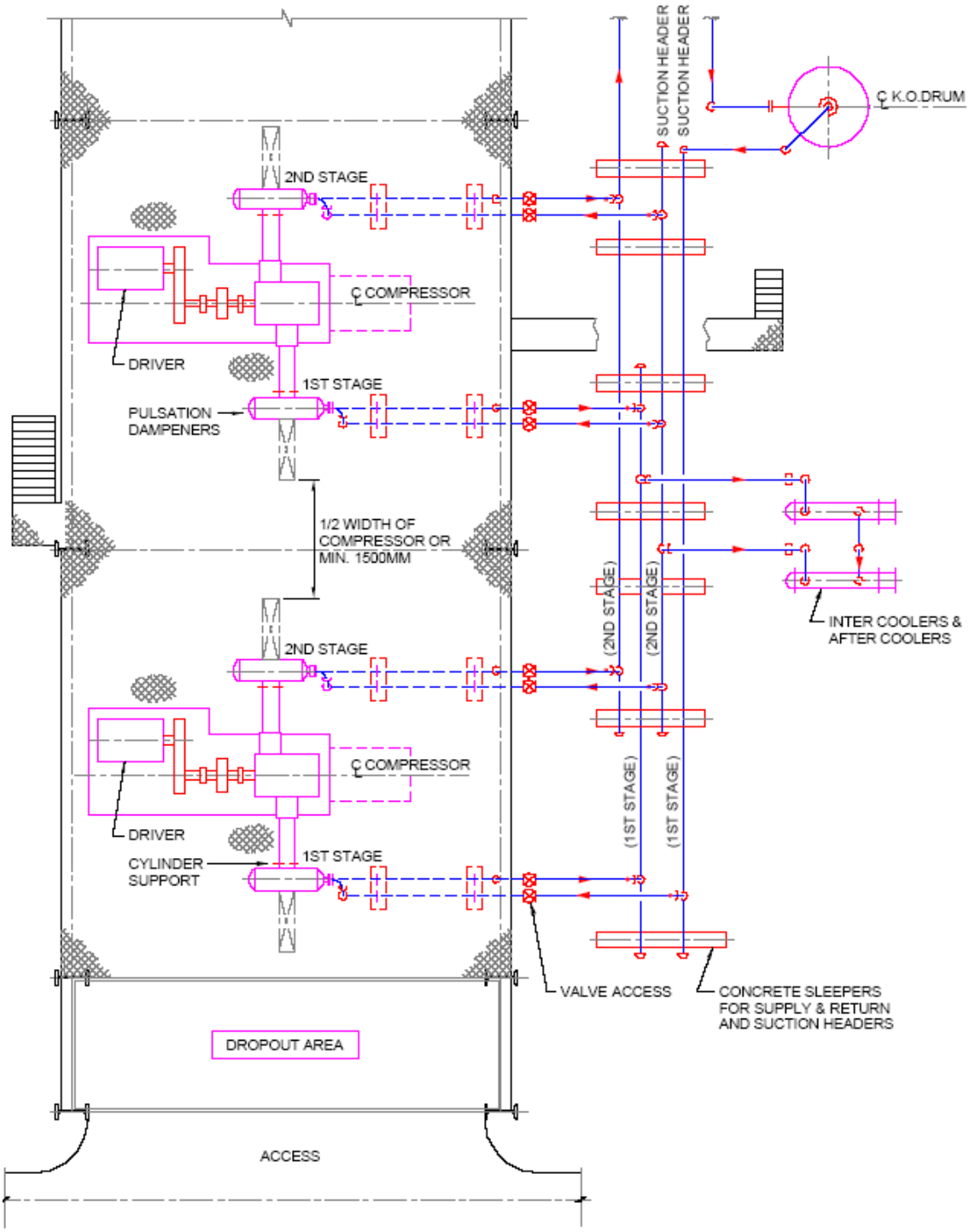
- The compressor house piping consist of suction / discharge piping, auxiliary equipment piping and utility system piping. The main suction line with its components shall be as short and direct as possible. The discharge line with its main components shall be routed clearing the compressor and its driver and supported independent of compressor foundation or building column foundation. This will minimize the transmission of damaging vibrations to the building structure / frame.
- Suction & discharge piping should preferable be run as close to grade level as possible to facilitate supporting.

- The vendor furnishes P&ID for the compressor with its auxiliary equipment. These drawings should be reviewed fully for the provisions of vents and drains requirement of the installation.

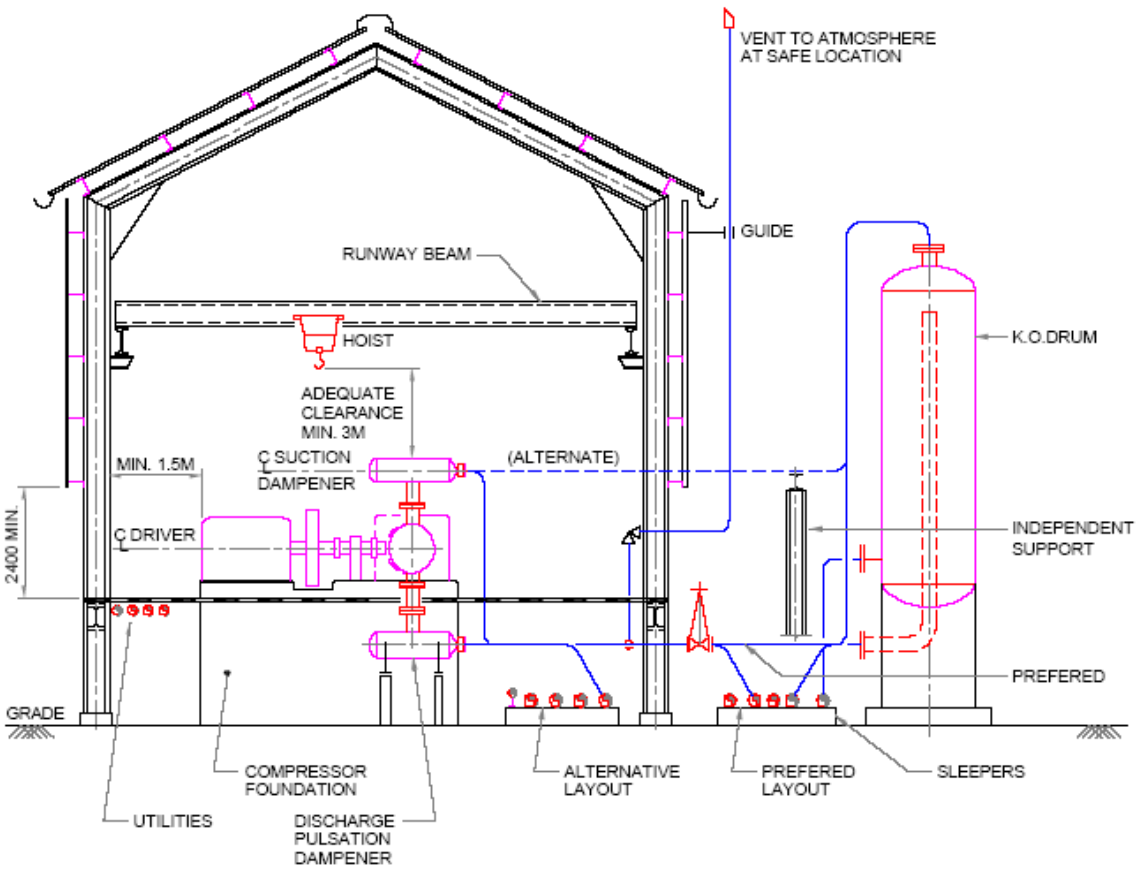
- For reciprocating compressors, API 618 provides the acceptance criteria for nozzle loads. For centrifugal compressors, API 617 provides the acceptance criteria for nozzle loads.

- Reciprocating compressor piping arrangement should be finalized after analog study, which identifies potentially damaging acoustic or pulsation problems during design phase itself.

RECIPROCATING COMPRESSORS - PIPING STUDY (PLAN)



RECIPROCATING COMPRESSORS - PIPING STUDY (ELEVATION)



PIPING STUDY
HEAT EXCHANGER PIPING

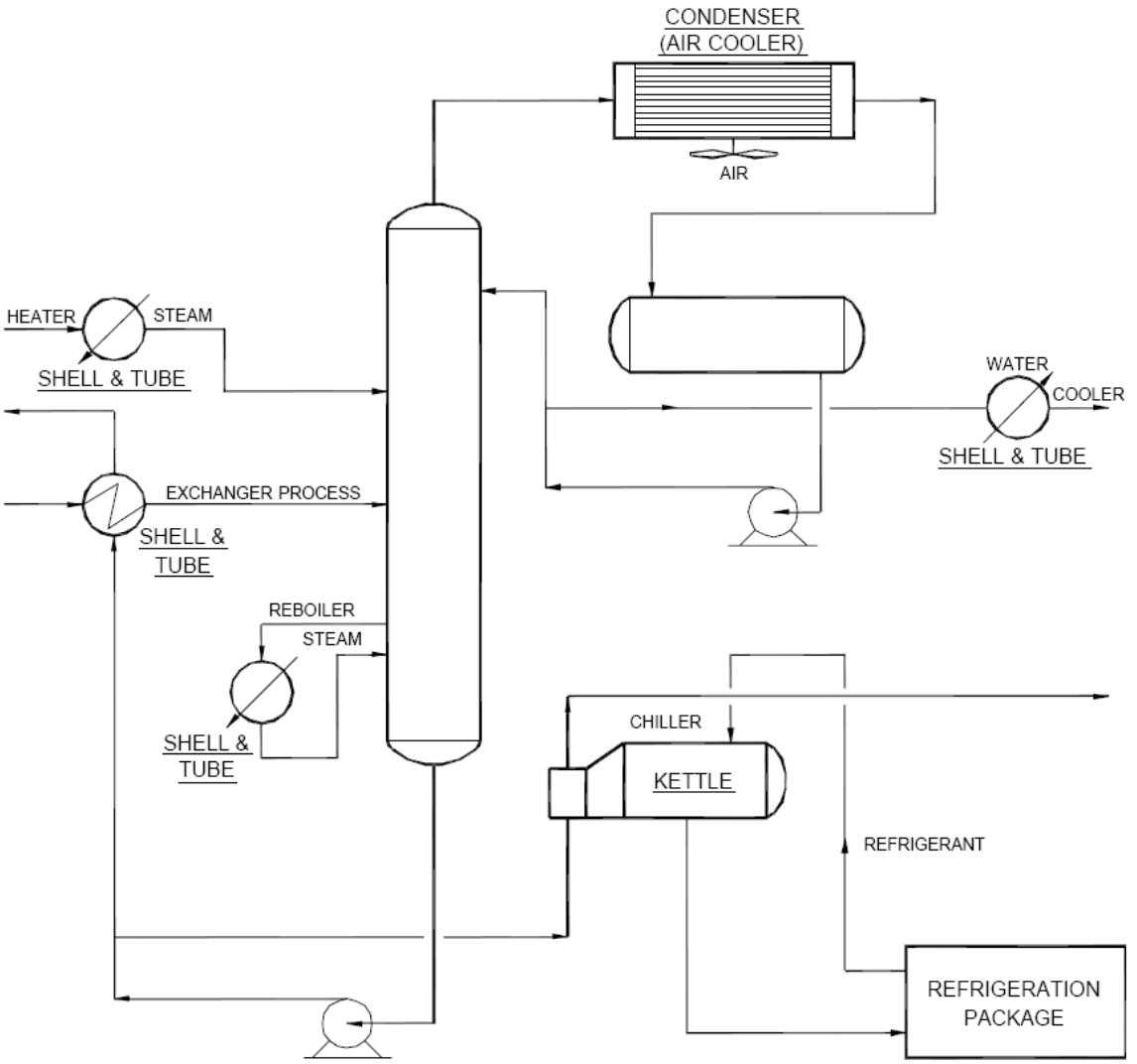
INTRODUCTION

Heat Exchangers are widely used equipments in the chemical, petrochemical and refinery type of plant. The control of heat within a plant operation is done by direct heat application in a furnace, or by heat exchange in a shell and tube exchanger / plate heat exchanger. The principal application of heat exchanger is to maintain a heat balance through the addition or removal of heat by exchange with outside source or between steams / process fluids of two different operating temperatures.

APPLICATION

The most common application of heat exchanger is illustrated on the below given PFD.

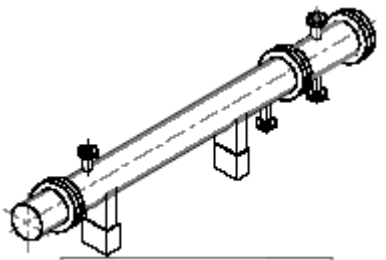
- Cooler – cools process steams by transferring heat to cooling water, atmosphere & other media.
- Exchanger – Exchanges heat from hot to cold process steams.
- Reboiler – Boils process liquid in tower bottoms by using steam, hot oil or process steam as the heating medium.
- Heater – Heat the process steams by condensing steam.
- Condenser – Condenses vapors by transferring heat to cooling tower, atmospheric air, or other media.
- Chiller - Cools a process streams to a very low temperatures by evaporating a refrigerant.



EXCHANGER APPLICATION SHOWN ON A PROCESS FLOW DIAGRAM

TYPES OF EXCHANGER

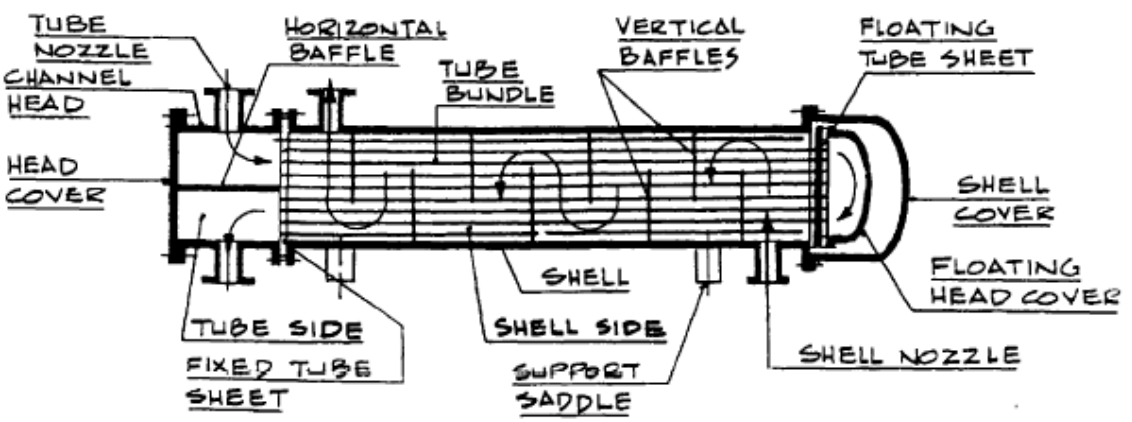
Briefly, exchangers, etc., can be divided into the following three groups :



SHELL AND TUBE EXCHANGER

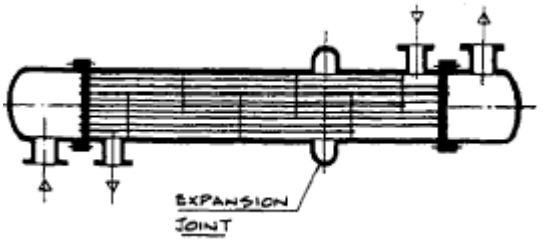
1. Shell & Tube Exchanger

It can be vertical or horizontal with the horizontal ones single or stacked in multi-units. As the name suggests, they consist of a cylindrical shell with a nest of tubes inside.



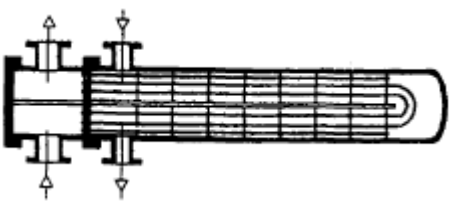
Shell & Tube Exchanger construction details

In general there are three types of shell & Tube Exchanger



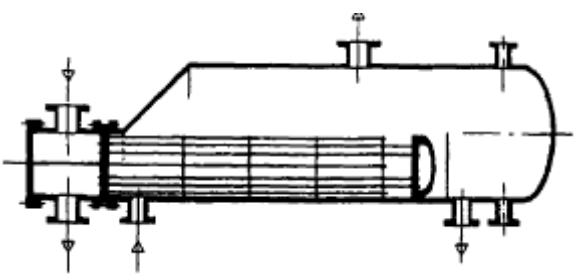
a) ***Fixed Tube Exchanger***

- Have no provision for the tube expansion and unless a shell expansion joint is provided. Fixed tube exchangers are used when the temperature differences between shell side and tube side fluid are small.



b) ***U-Tube Exchanger.***

- Tubes can expand freely. Floating head or U-type exchangers are used where there is a significant temperature difference.



c) Kettle Exchanger

- Kettle -type reboilers are used for evaporation in case of limiting pressure drop, otherwise vertical reboilers are used for evaporation.

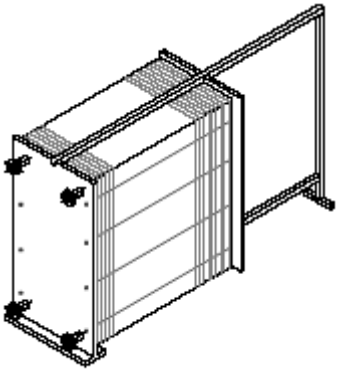


PLATE EXCHANGER

2. Plate Exchanger

- Plate heat exchangers are generally used in low-pressure, low temperature applications. The plate exchanger occupies less space than shell and tube exchanger for equivalent heat exchanger surface.

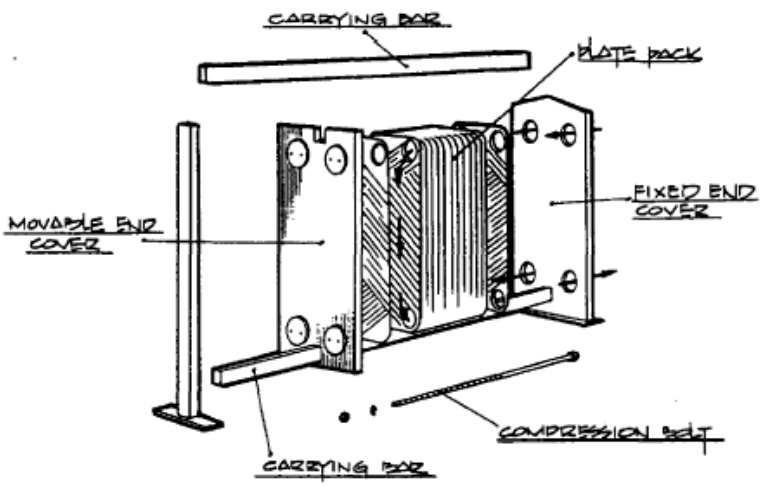
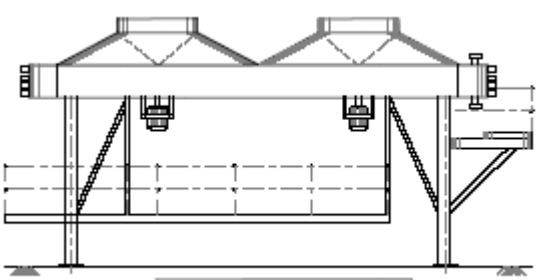


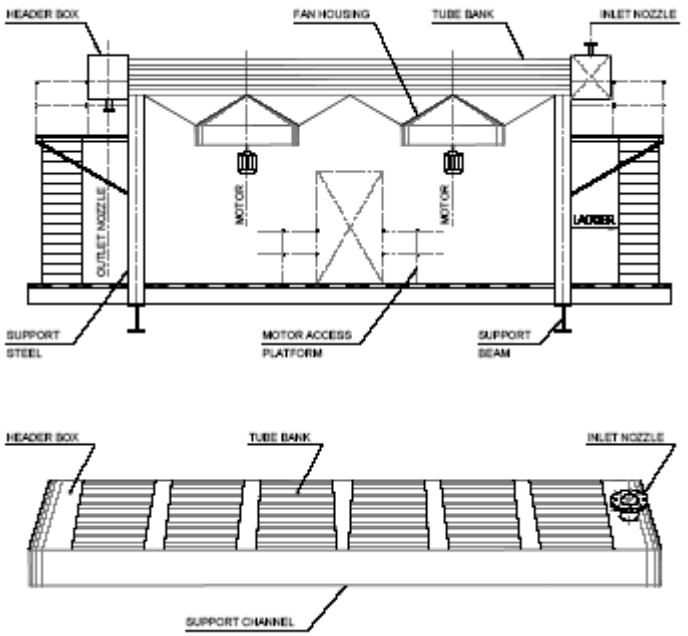
Plate Exchanger construction details

2. Air Cooler Exchanger



AIR COOLER EXCHANGER

- Aircoolers are used for overhead condensers of column and consist of fin-tube bundles with a header box to each end, having inlet on top of header-box at one end and outlet on bottom of header box at the other end.



Air Cooler construction details

ALTERATION THAT CAN MADE TO SHELL & TUBE EXCHANGER

Interchange, flowing media between the tube and shell side. This change is often possible, more so when the flowing media are similar, for example, liquid hydrocarbons. Preferably the hotter media should flow in the tube side to avoid heat losses through the shell, or the necessity for thicker insulation.

Change direction on flow on either tube or shell side. On most exchangers in petrochemical plants, these changes are frequently possible without affecting the required duty of the exchanger if the tubes are in double or multi - pass arrangement and the shell has cross flow arrangement.
In exchangers where counterflow conditions can be arranged, changing of flow direction should be made simultaneously in tube and shell. Some points to consider when contemplating a flow change are :

Shell leakage : When water cooling gases, liquid hydrocarbons or other streams of dangerous nature it is better to have the water in the shell and the process in the tubes, since any leakage of gas, etc., will contaminate the water rather than leaking to atmosphere.

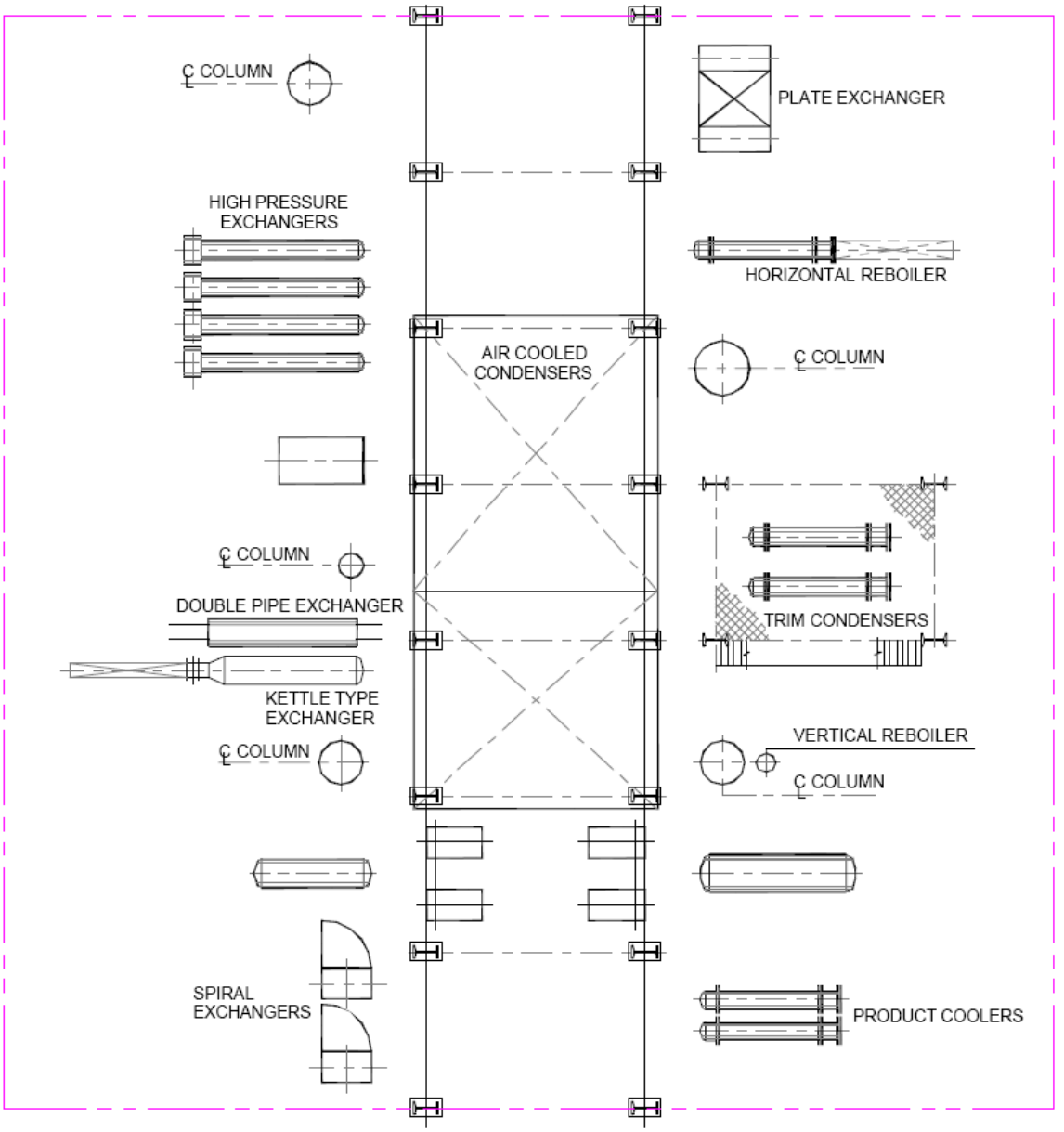
High pressure conditions : It is usually more economical to have high pressure in the tubes than in the shell as this allows for minimum wall thickness shell.

Corrosion : Corrosive fluids should pass through the tubes, thus allowing the use of carbon steel for the shell.

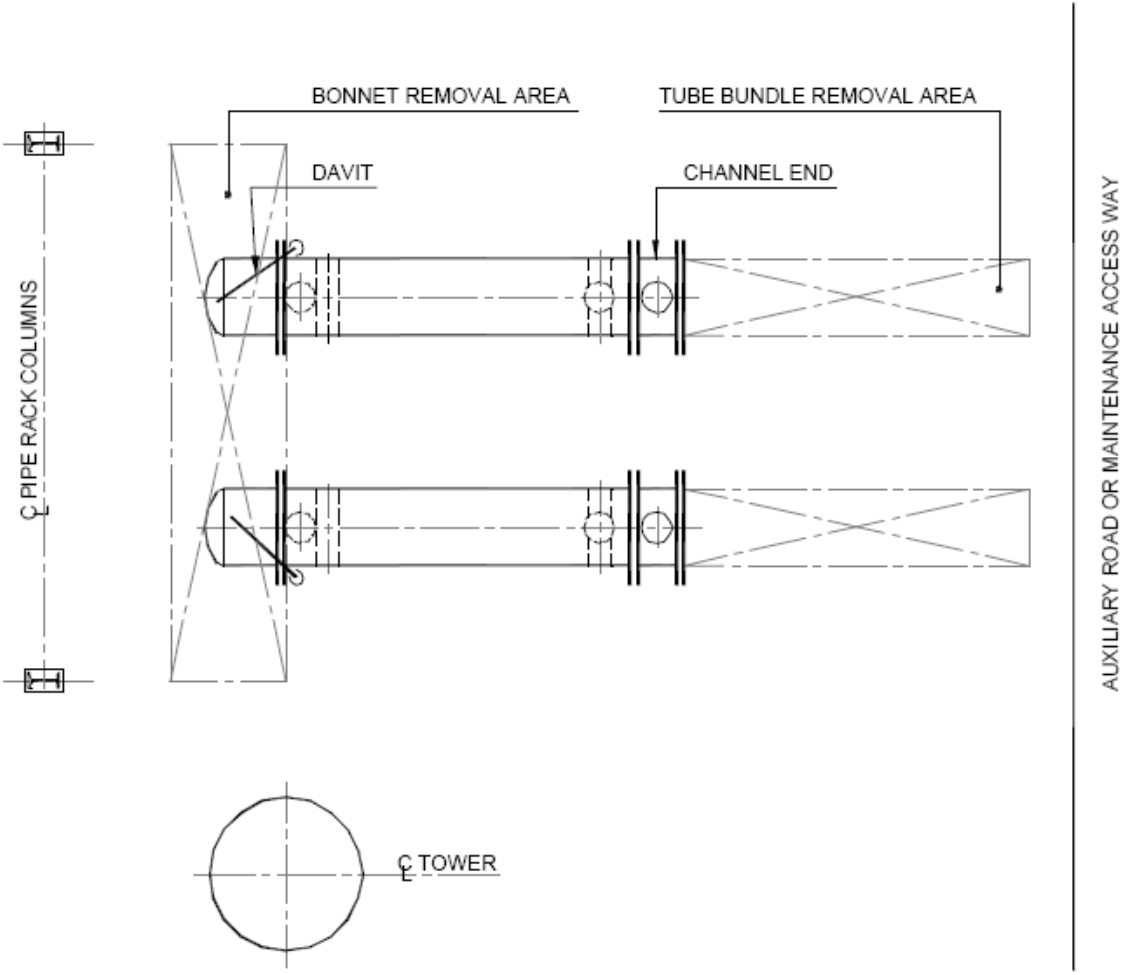
Fouling : It is preferable to pass the clean stream through the shell and the dirty through the tubes. This allows for easier cleaning. Mechanical changes, such as tangential or elbowed nozzles can sometimes assists in simplifying the piping or lowering stacked exchangers.

LOCATION & SUPPORT

Exchangers should be located close to the major equipment with which it is associated in PFD / P&ID. Reboilers are placed next to their respective towers and condensers are placed over reflux drums. Exchangers between two distant pieces of process equipment should be placed at optimal points in relationship to pipe racks. Most exchangers are to be located at grade level with elevations to have a clearance of 1m above Finished Ground Level (FGL). Elevated exchangers may be necessary to fulfill the NPSH requirement of a downstream centrifugal pump.



Typical Plot Plan of Several Exchangers



- CHANNEL END TO FACE MAINTENANCE ACCESS WAY FOR TUBE BUNDLE REMOVAL.
- PROVISION OF ADEQUATE SPACE FOR BONNET REMOVAL.

Typical Exchanger Orientation

In case of large numbers of heat exchangers, they are grouped in one or more category to save pipe work, structural work, provision of lifting and maintenance facilities, platform requirement etc. Paired or grouped exchnagers shall be spaced to allow minimum 450mm preferably 600mm between the outside of adjacent channel or bonnet flanges to facilitate access to flange bolts during maintenance. Adequate space shall be provided on either side of paired exchanger and at both ends of grouped exchanger for control and operator access as illustrated in Fig.

ESTABLISHING ELEVATION OF EXCHANGER

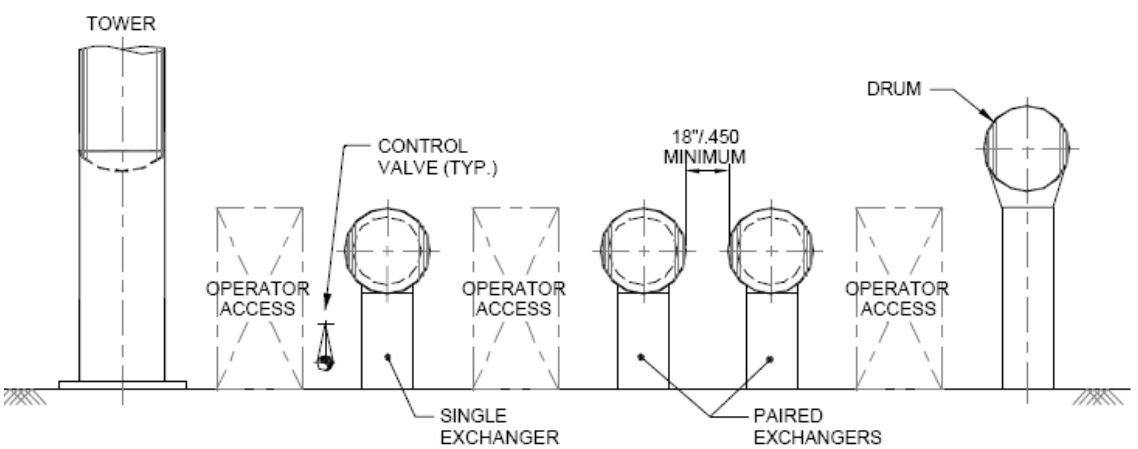
Where process requirements dictate the elevation, it will usually be noted on the P and I diagram. From the economic point of view, grade is the best location, where it is also more convenient for the tube bundle handling and general maintenance. Exchangers are located in structures when gravity flow is required to the collecting drum, or where the outlet is connected to a pump suction, which has specific NPSH requirements. To elevate exchangers without specific requirements, the following procedure is recommended:

Select the exchanger with the largest bottom connection; add to the nozzle standout dimension (center line of exchanger to face of flange) the dimension thru hub of flange, elbow ($1\ ^{1}/_{2}$ dia), one - half the O/S pipe diameter and 300 mm for clearance above grade.

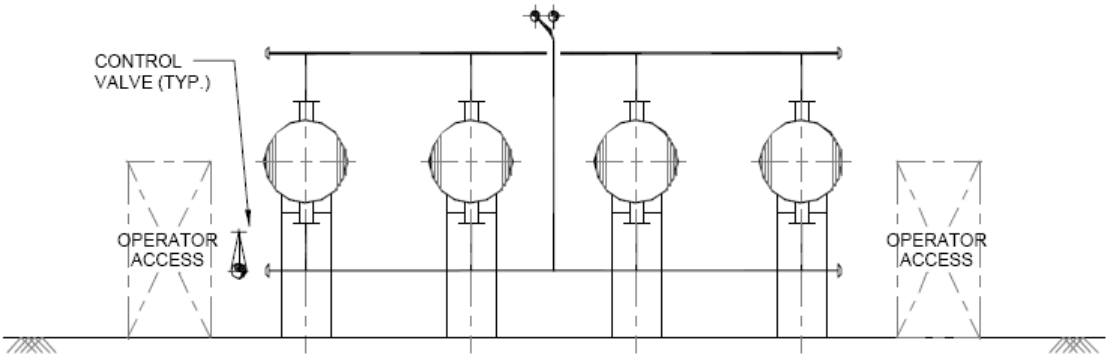
Now subtract the center line to under-side of support dimension from above, and the dimension remaining is the finished height of the foundation including grout.

It is preferable if this foundation height can be made common for all the exchangers in the bank. If this is impracticable due to extremes of shell and/or connection pipe sizes, then perhaps two heights can be decided upon.

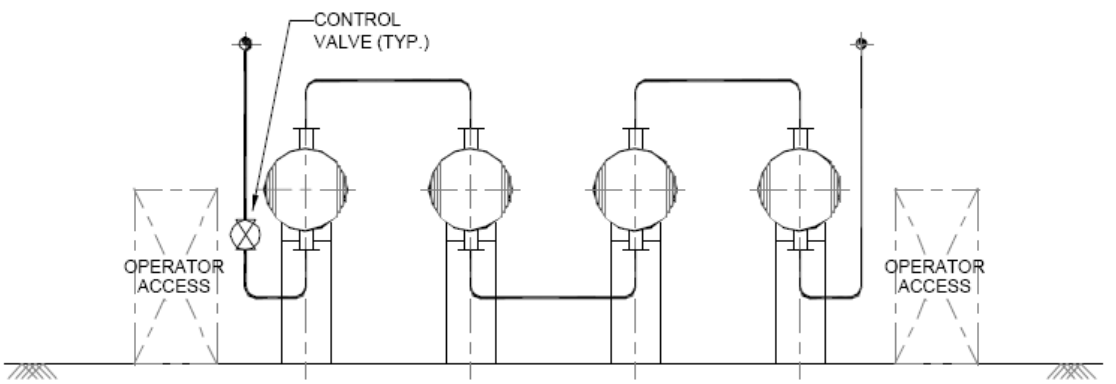
When stacking exchangers, two or three high, it is desirable that overall height does not exceed 12’ 0” (3650 mm) due to the problem of maintenance, bundle pulling, etc.



Sample Single & paired Exchanger.

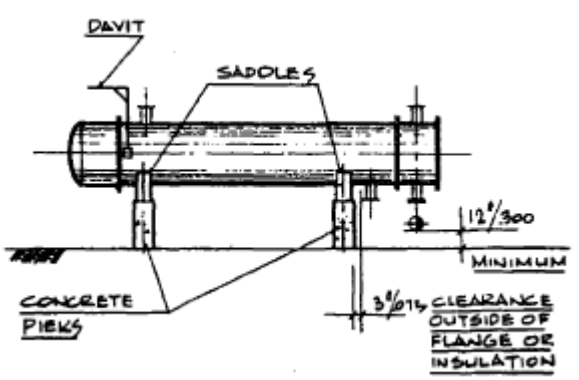


Parallel Exchanger Installations.

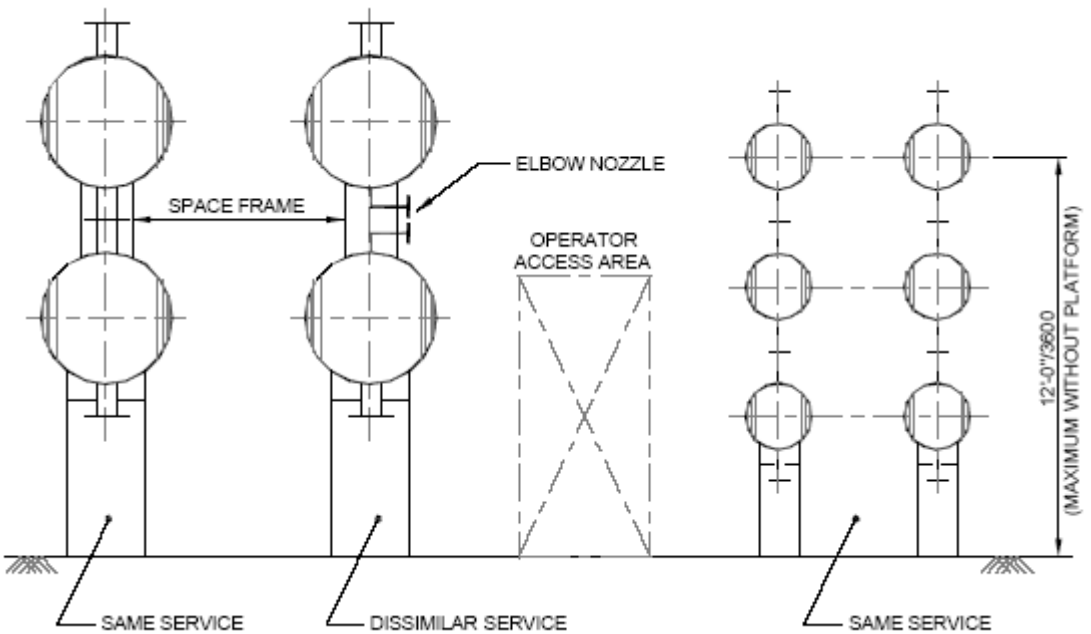


Series Exchanger Installations.

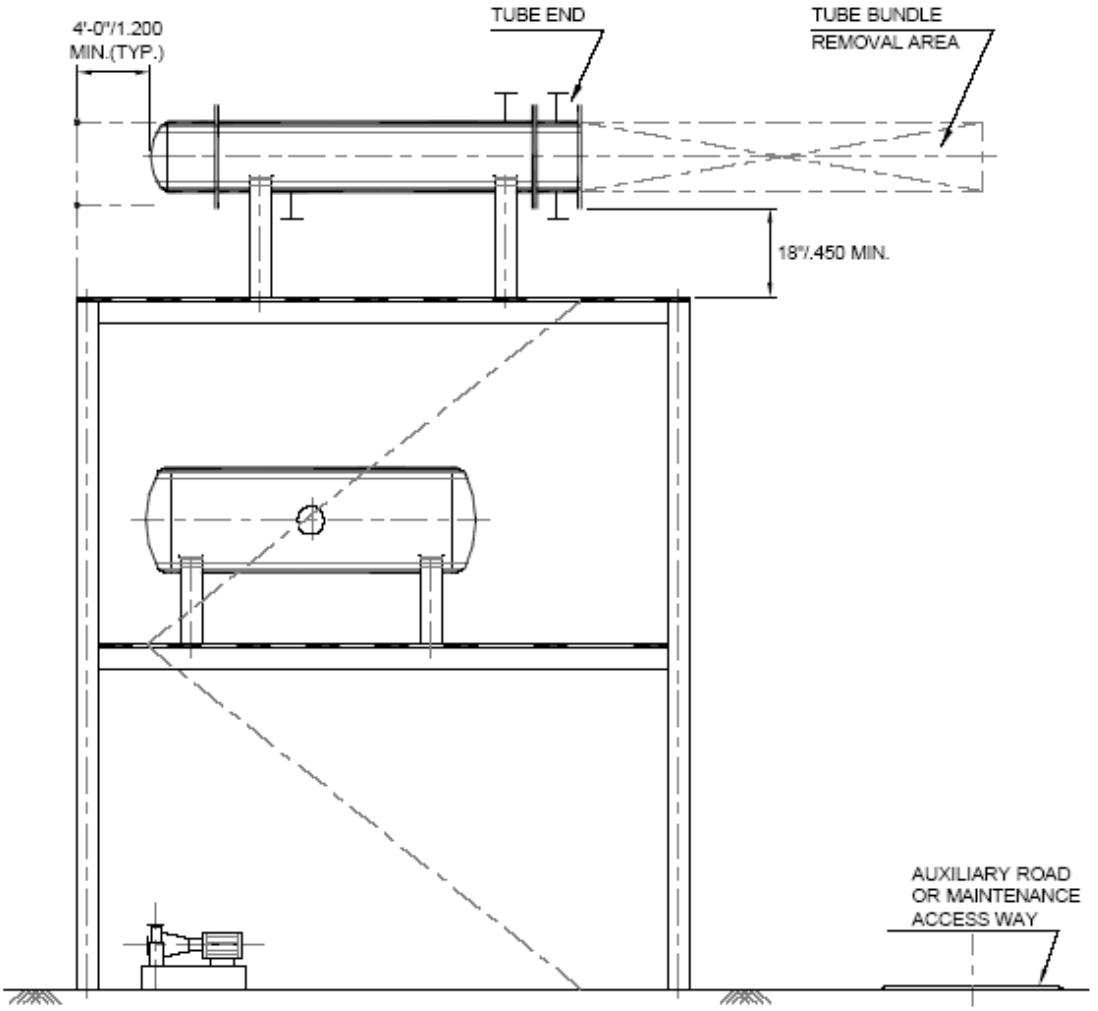
The support saddle with oblong holes for provision of thermal expansion are normally located on the saddle farthest from the channel end but the final location depends on the plant layout and the stress analysis of the connected piping.



Exchanger piping should be as direct and simple as possible by considering alternatives such as arranging exchangers side by side / stacking them for reversing flows.
Exchangers are sometimes mounted on structures, process columns and other equipment.
Special arrangements for maintenance and tube cleaning should be provided in such cases.

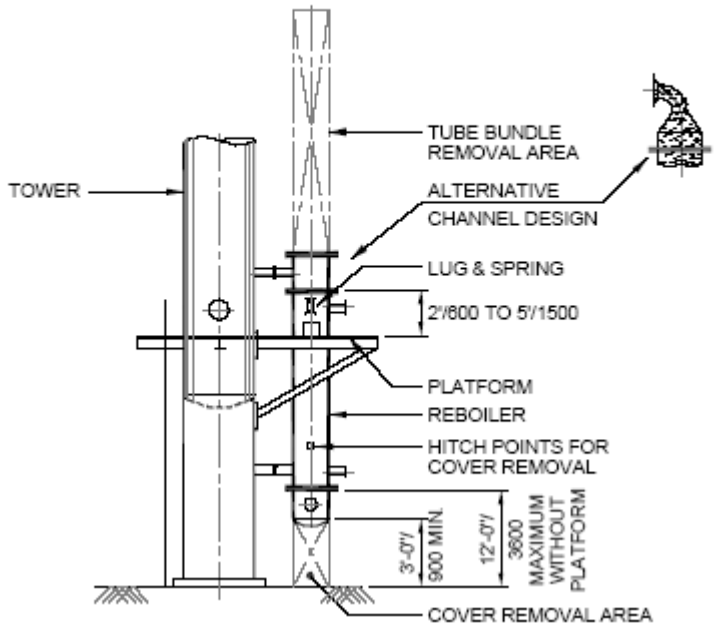


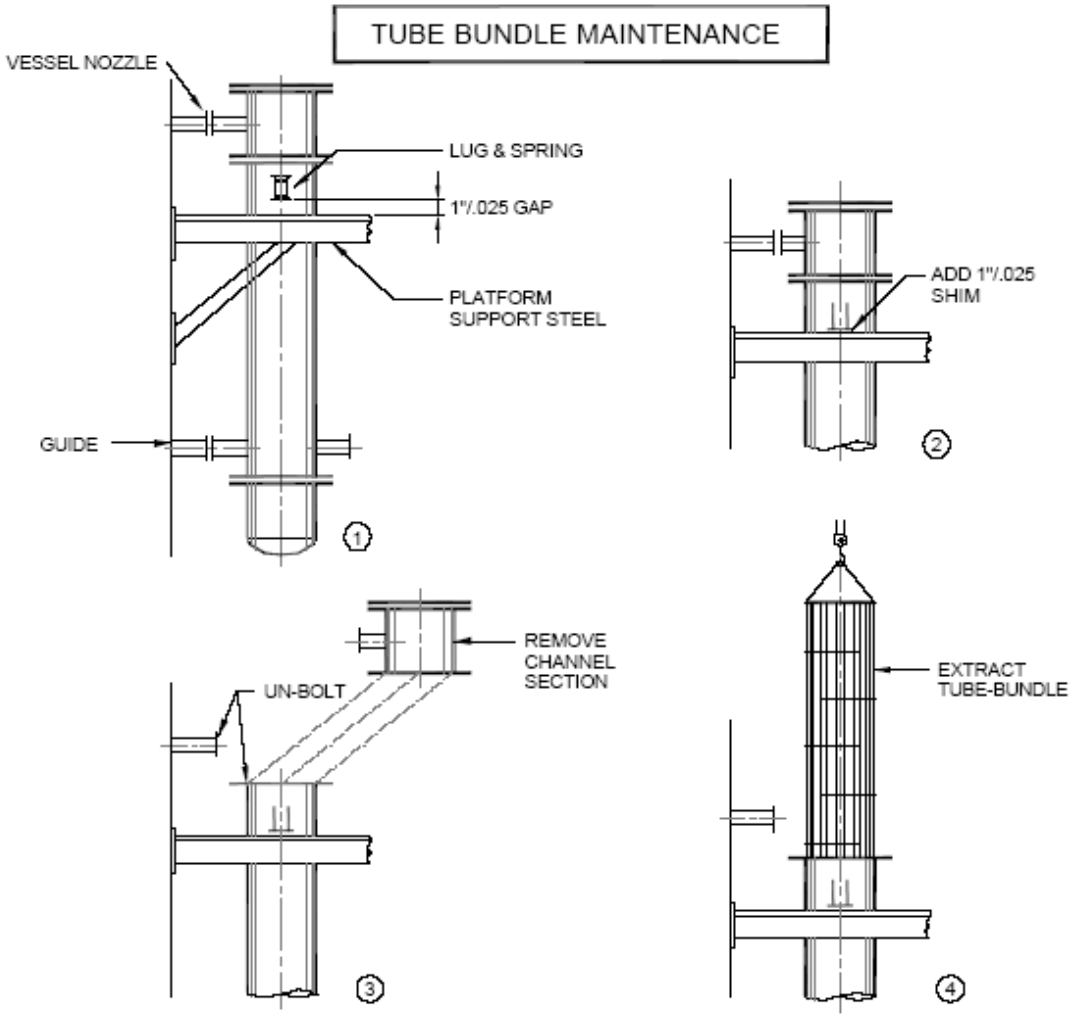
Stacked Exchanger Installations.



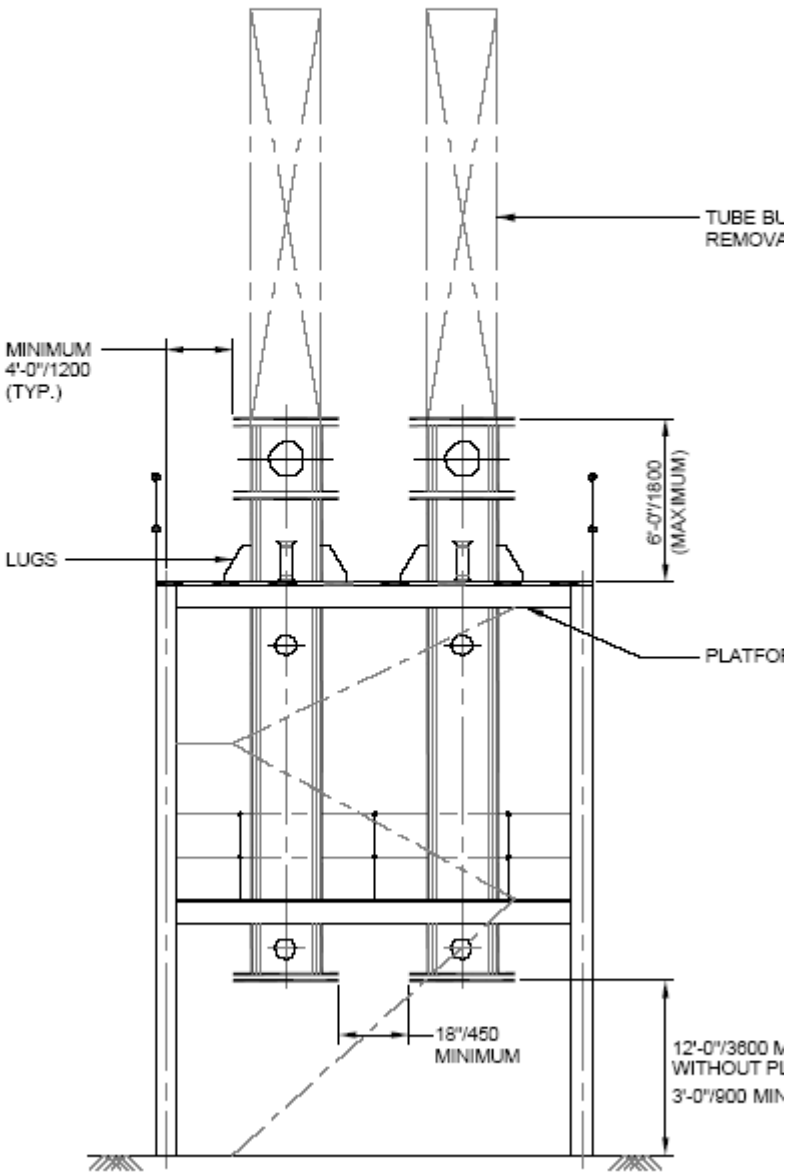
Sample Structure Mounted Exchanger Installations.

TOWER SUPPORTED VERTICAL INSTALLATION




TUBE BUNDLE MAINTENANCE
VESSEL NOZZLE
LUG & SPRING
1"/.025 GAP
PLATFORM
SUPPORT STEEL
GUIDE
1
ADD 1"/.025
SHIM
2
REMOVE
CHANNEL
SECTION
UN-BOLT
3
EXTRACT
TUBE-BUNDLE
4

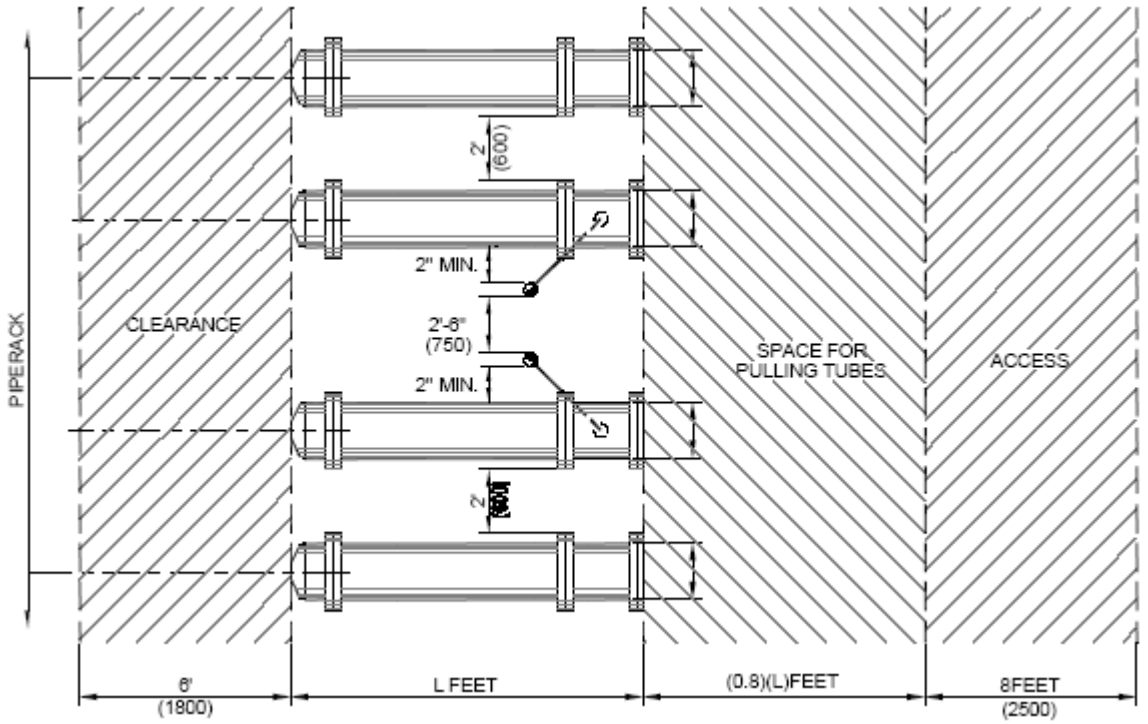
STRUCTURE SUPPORTED VERTICAL INSTALLATION



ACCESS FOR OPERATION & MAINTENANCE

Internals of heat exchanger require periodic cleaning and repair. It is important that exchangers and the surrounding piping are arranged to facilitate access to the internal parts.

- Horizontal clearance of at least 900mm should be left between exchangers flange to flange or exchanger flanges to piping. Where space is limited, clearance may be reduced between alternate exchangers but in no case clearance over insulation between channel flanges shall be less than 600mm.



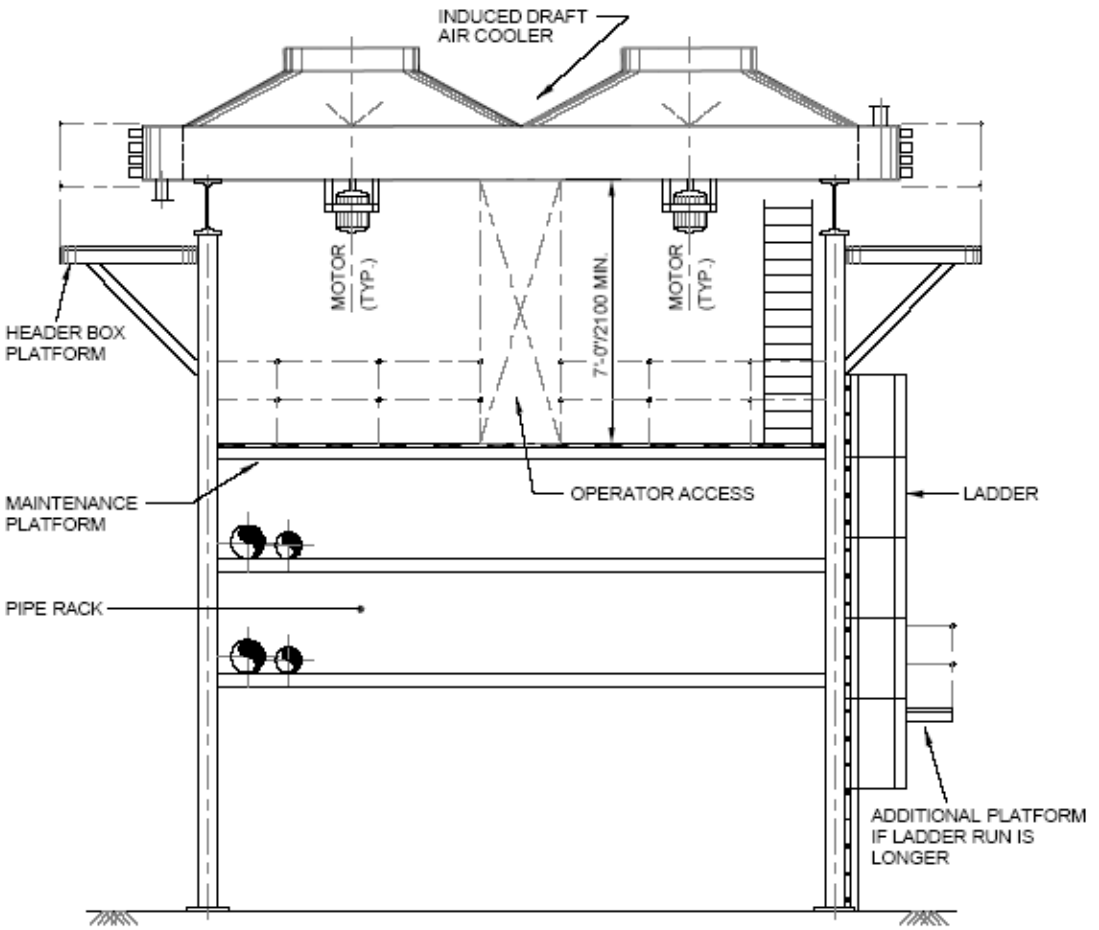
- The channel ends of exchangers should face the local access road for tube bundle removal the shell cover should face the pipe rack. A typical exchanger arrangement with clearance for access, operation and Pulled out bundles should not extend over main access road. Maintenance is shown in **Fig.** Access for tube bundle removal is usually 500mm more than the bundle length.

- Mobile equipment should be used for handling tube bundles and covers at grade level. Expensive built-in facilities e.g. lifting beams, monorails to be kept minimum.

- The use of tube-bundle extractor eliminates the need for permanent tube bundle removal structures. These mechanisms weigh around seven tons and are capable of pull forces about 500,000lbs. The tube-bundle is held in position by crane and balanced by the extractor's leveling cradle and pulled out of its shell with pull rod attachments that use hydraulic force.

- Provision of easily removable spool pieces, flanged elbows, break flanges or short pipe runs will be helpful for maintenance of exchangers.

- For air-cooled exchangers, platform arrangements must suit maintenance access requirements. Considerations must be given to fin-tube bundle removal, tube rodding out at header boxes, motor and fan access.



HEAT EXCHANGER PIPING

1 . SHELL & TUBE

- After all the required information has been collected for the piping design of a heat exchanger, the first step is to outline clearance and working space in front and around both ends of the exchanger. These working spaces should be kept clear of any piping and accessories to facilitate channel, shell-cover and tube-bundle removal as well as maintenance and cleaning.

- The free space at the side of horizontal shell can be used for placement of control stations.

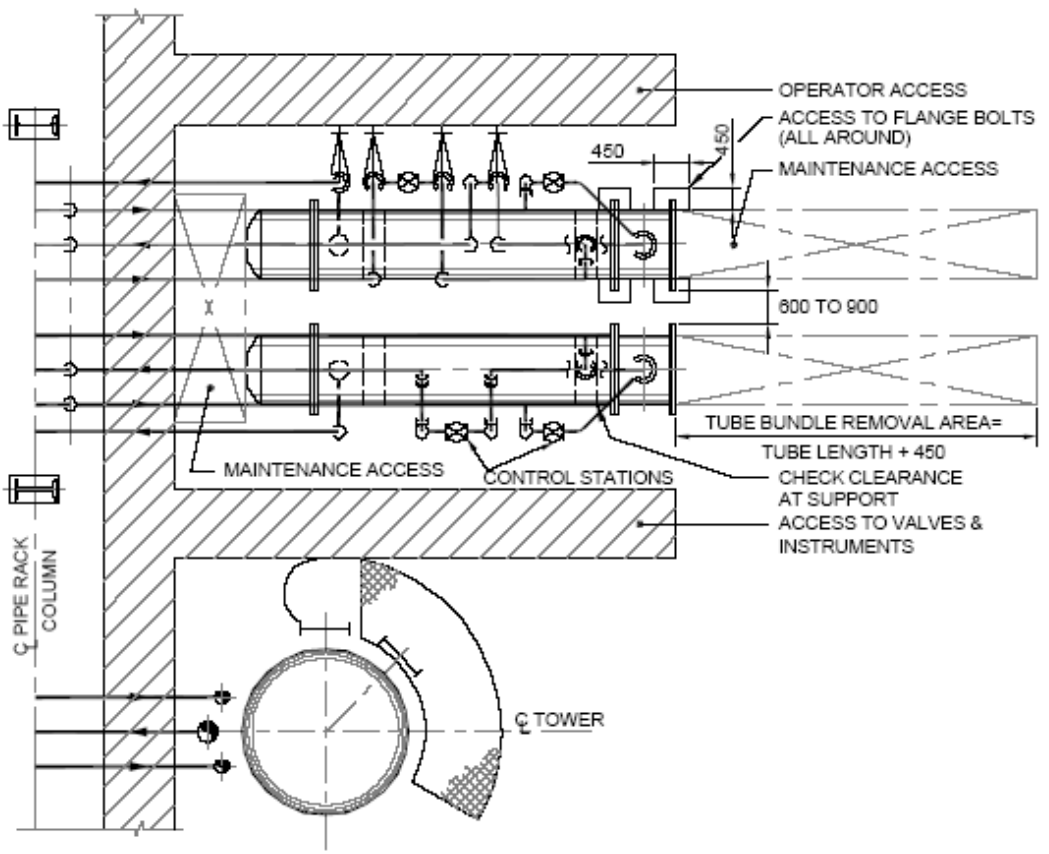
- The piping is elevated from grade to have a clearance of 300mm above the grade level. The pipingconnected to channel head nozzles should be furnished with break flanges to facilitate the removal of the channel head.

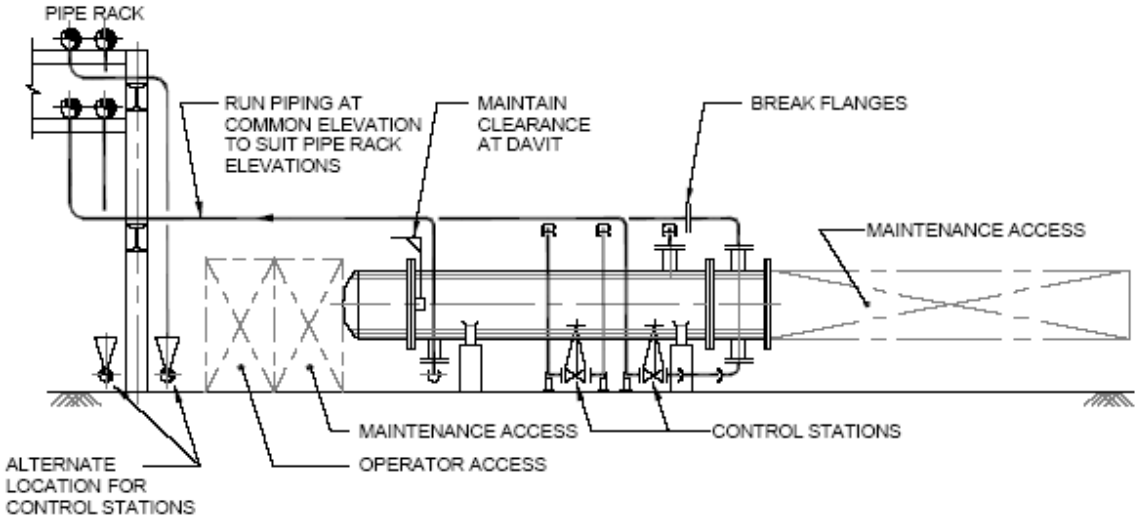
- Steam lines connecting to a header in the yard can be arranged on either side of the exchanger centerline without increasing the pipe length.

- Cooling-water lines, if under ground, should run right under the lined-up channel nozzles of all coolers.

- Access to valve hand wheels and instruments will influence the piping arrangement around heat exchangers. Valve hand wheels should be accessible from grade and from a convenient access way. These access ways should be used for arranging manifolds, control valves and instruments.

PIPING ARRANGEMENT FOR HORIZANTAL SHELL & TUBE EXCHANGER

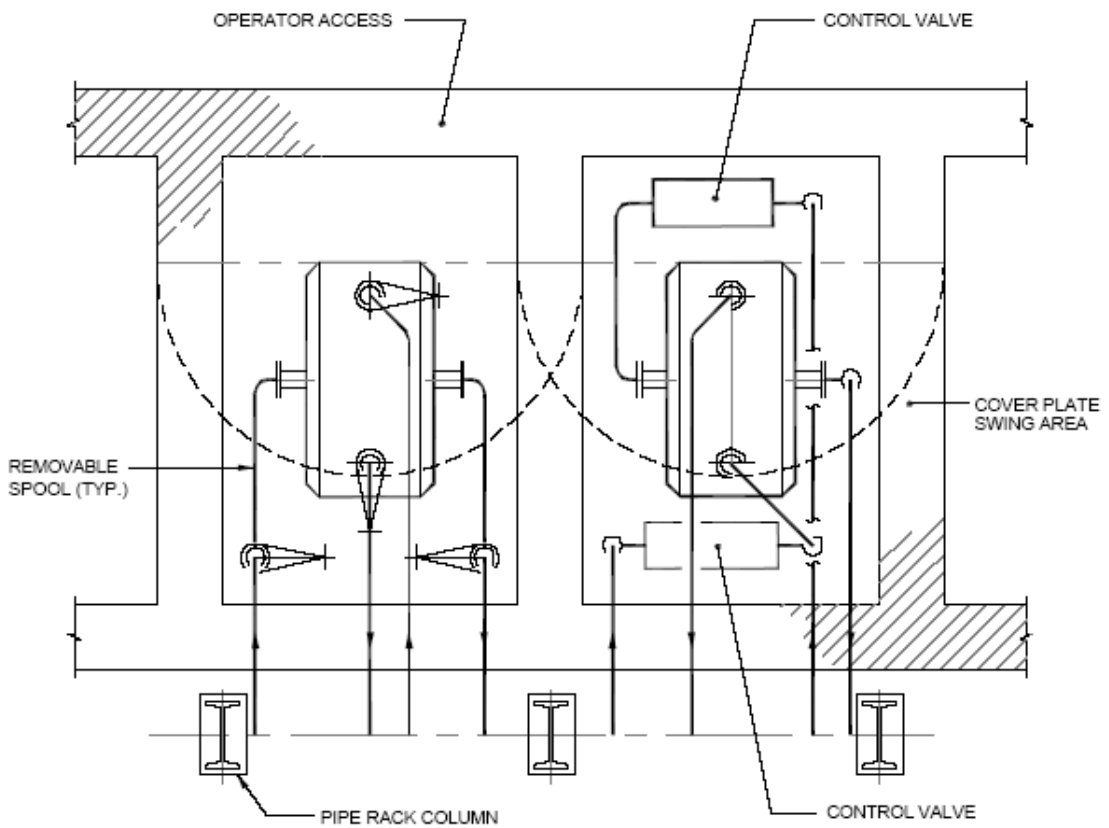




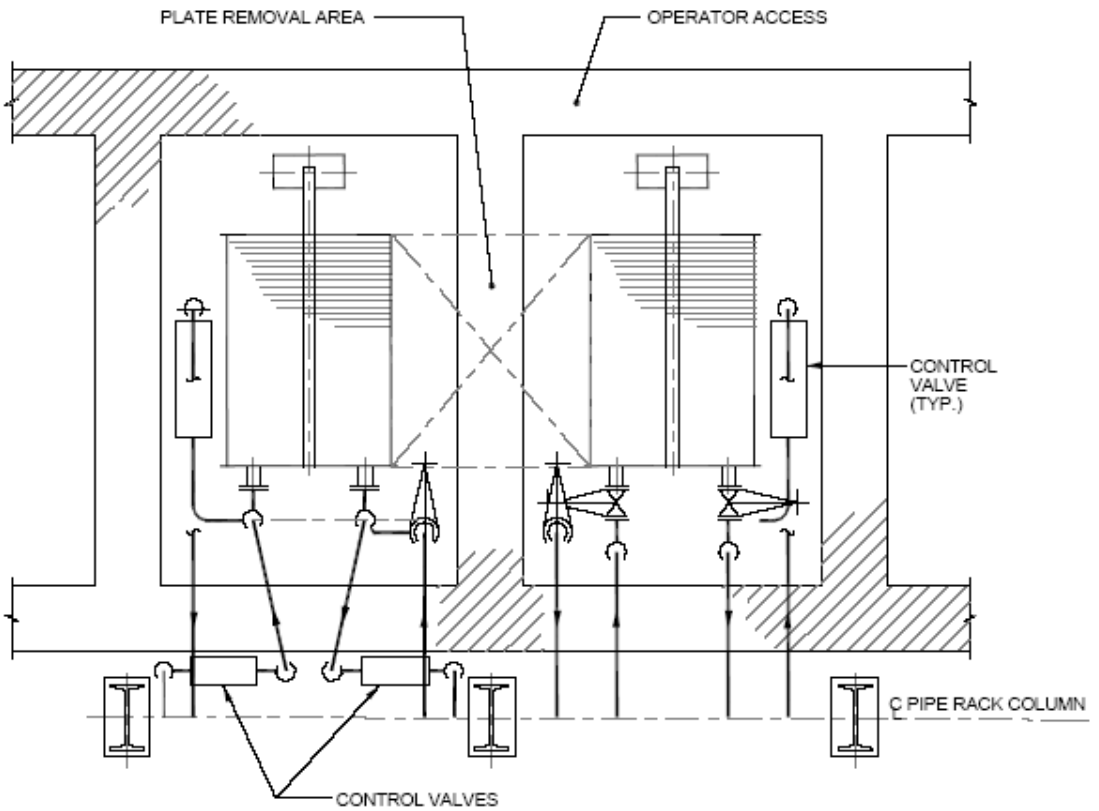
2. PLATE & SPIRAL EXCHANGERS

Piping at spiral and plate exchangers is also arranged to allow opening of covers and removal of plates. Controls at the spiral exchanger are located on the ends of the unit, clear of the cover plate swing area, piping attachment to cover plate nozzles of spiral exchanger will have break flanges.
Controls for plate exchanger are located at the front and one side of the exchanger. The piping is elevated to have clearance from grade as well as convenience for operation of valves.
Fig.HEP29 and **HEP30** illustrate the typical piping arrangements around spiral & plate exchangers.

PIPING ARRANGEMENT FOR SPIRAL EXCHANGERS



PIPING ARRANGEMENT FOR PLATE TYPE EXCHANGERS

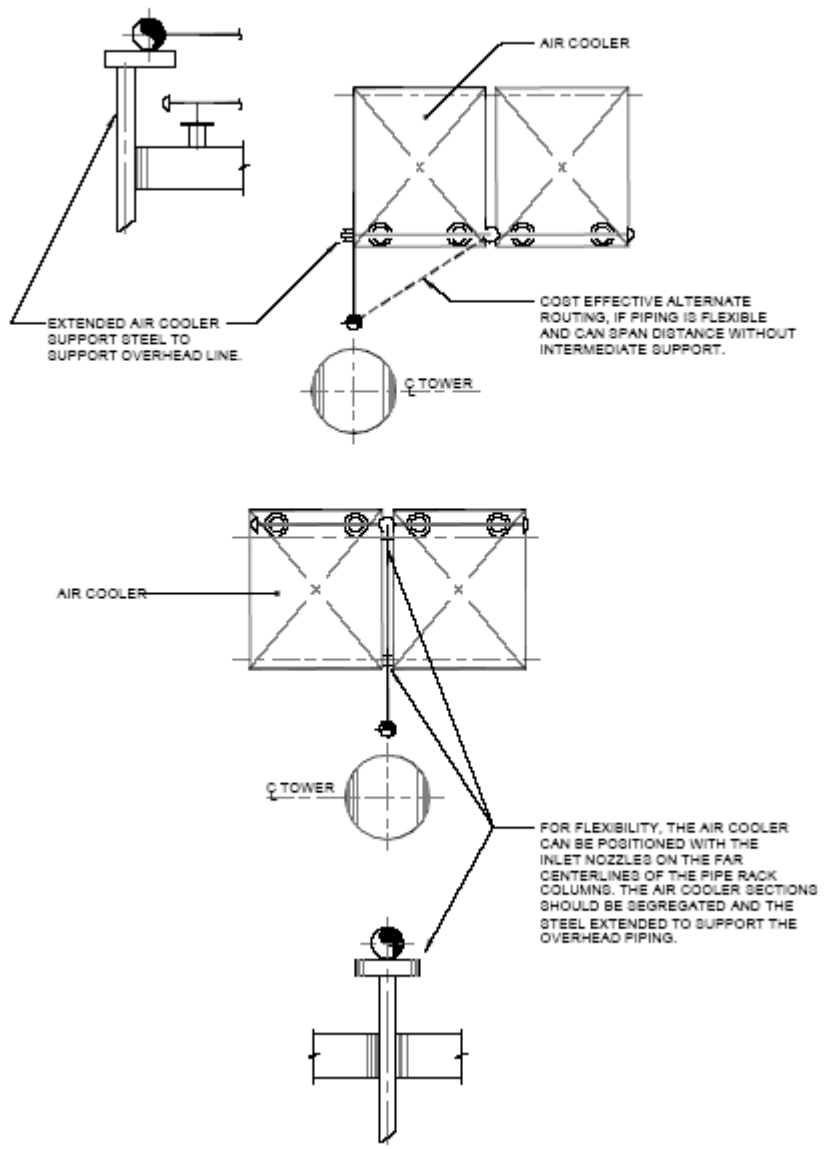


PLAN

3 . **AIR COOLERS**

Piping for air coolers are not routed over tube banks or fans and should be kept clear of the designated space for motor maintenance.

OVERHEAD PIPING ARRANGEMENTS FOR A CONDENSING AIR COOLER


AIR COOLER
EXTENDED AIR COOLER SUPPORT STEEL TO SUPPORT OVERHEAD LINE.
COST EFFECTIVE ALTERNATE ROUTING, IF PIPING IS FLEXIBLE AND CAN SPAN DISTANCE WITHOUT INTERMEDIATE SUPPORT.
℄ TOWER
AIR COOLER
℄ TOWER
FOR FLEXIBILITY, THE AIR COOLER CAN BE POSITIONED WITH THE INLET NOZZLES ON THE FAR CENTERLINES OF THE PIPE RACK COLUMNS. THE AIR COOLER SECTIONS SHOULD BE SEGREGATED AND THE STEEL EXTENDED TO SUPPORT THE OVERHEAD PIPING.

PIPING STUDY
COLUMN PIPING

INTRODUCTION

Towers are cylindrical steel vessel that is used for distilling raw material.

TYPES OF TOWER

Based on operation towers are classified as

i. Distillation Towers
ii. Absorption – Stripping Towers
iii. Fractionation Towers.

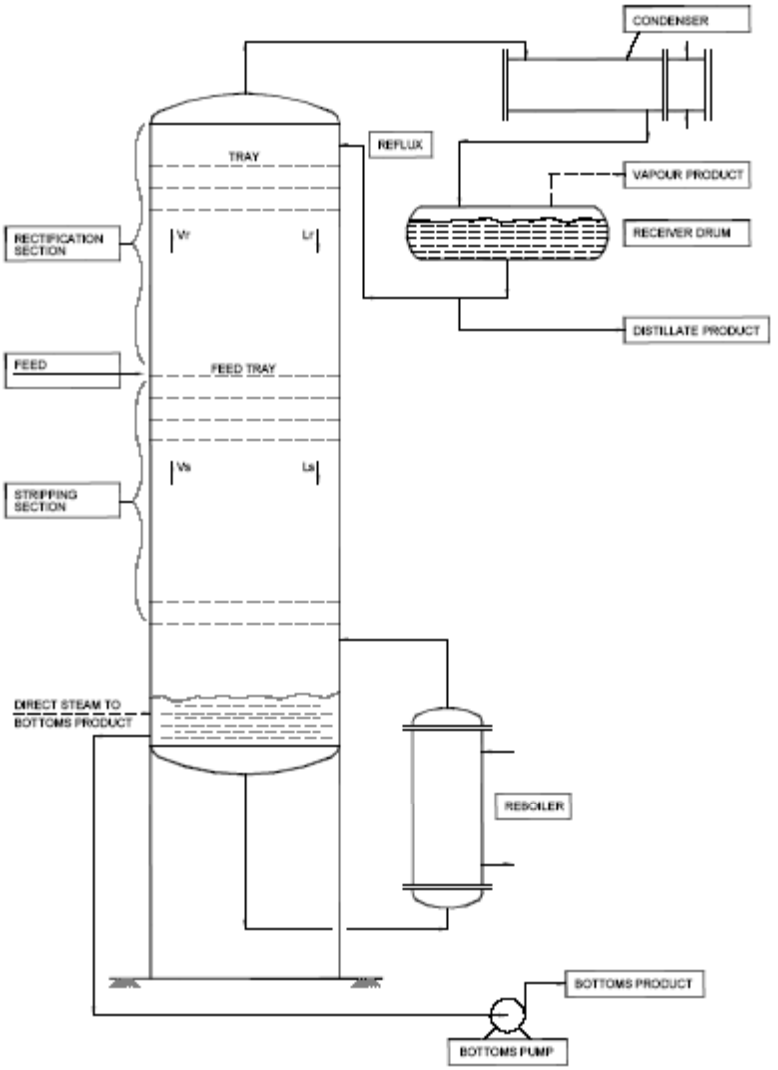
Distillation Towers:-

The distillation is separation of the constituents of a liquid mixture by partial vaporization of the mixture and separate recovery of vapor and residue.

The feed material, which is to be separated into fractions, is introduced at one or more points along the column shell. Due to difference in gravity between liquid and vapor phases, the liquid runs down the column, cascading from tray to tray, while vapor goes up the column contacting the liquid at each tray.

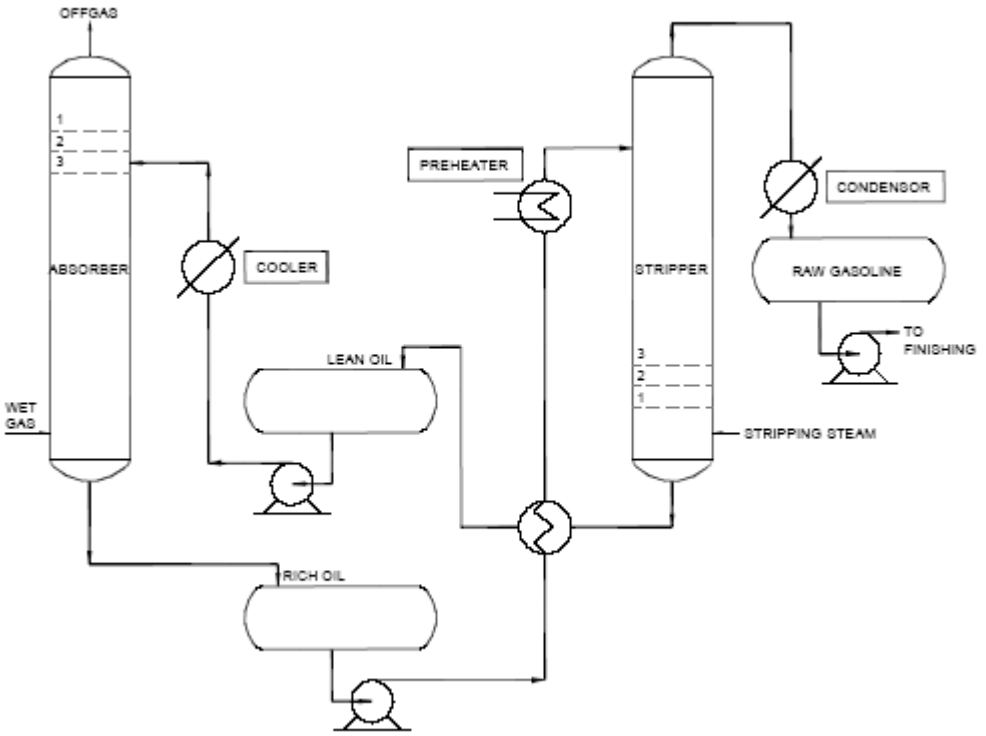
The liquid reaching the bottom of the column is partially vaporized in a heated reboiler to provide reboil vapor, which is sent back up the column. The remainder of the bottom liquid is withdrawn as the bottom product.

The vapor reaching the top of column is cooled and condensed to a liquid in the overhead condenser. Part of this liquid is returned to the column as reflux to provide liquid overflow and to control the temperature of the fluids in the upper portion of the tower. The remainder of the overhead stream is withdrawn as the overhead or distillate product.



Absorption – Stripping Towers

Many operations in petrochemical plants require the absorption of components from gas streams into lean oils or solvents. The resultant rich oil is then stripped or denuded of the absorbed materials. The greatest use of this operation utilizes hydrocarbon materials, but the principles are applicable to other systems provided adequate equilibrium data is available.



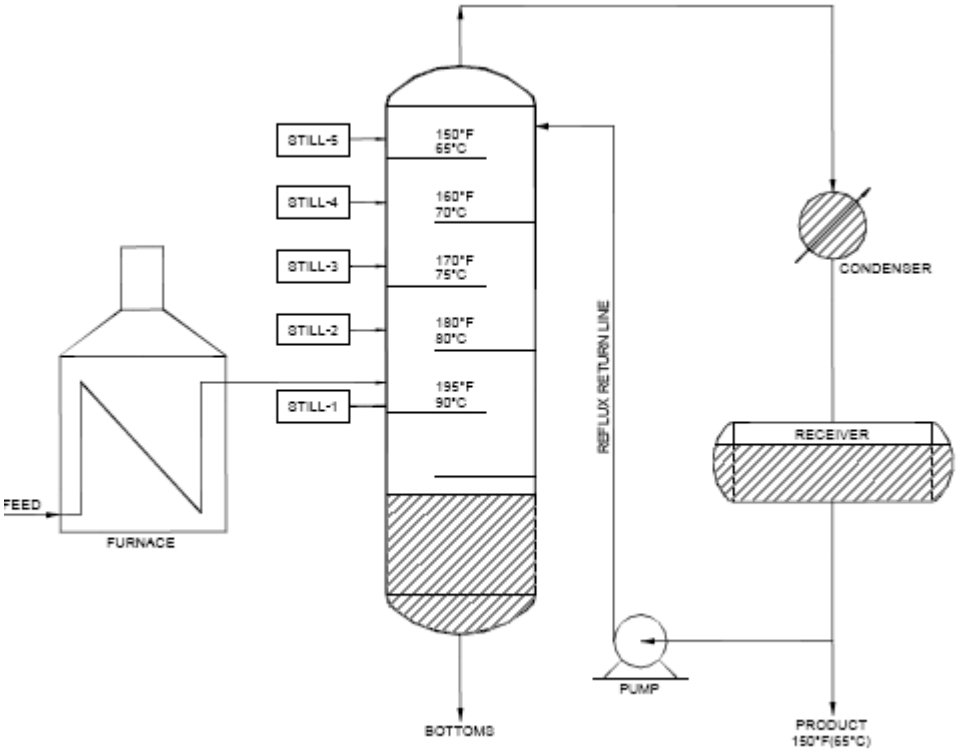
Fractionation Towers.

A fractionation column is a type of still. A simple still starts with mixed liquids, such as alcohol and water produced by fermenting grain etc. and by boiling produces a distillate in which the concentration of alcohol is many times higher than in feed. In petroleum industry, mixtures of not only two but a lot many components are dealt with. Crude oil is a typical feed for a fractionation column and from it; the column can form simultaneously several distillates such as wax distillate, gas oil, heating oil, naphtha and fuel gas. These fractions are termed cuts.

The feed is heated in a furnace before it enters the column. As the feed enters the column, quantities of vapor are given off by flashing due to release of pressure on the feed.

As the vapors rise up the column, they come into intimate contact with down flowing liquid. During this contact, some of the heavier components of the vapor are condensed and some of the higher components of the down flowing liquid are vaporized. This process is termed refluxing.

If the composition of the feed remains the same and the column is kept in steady operation, a temperature distribution establishes in the column. The temperature at any tray is the boiling point of the liquid on the tray. 'Cuts' are not taken from every tray. The P&ID will show cuts that are to be made, including alternatives. Nozzles on selected trays are piped and nozzles for alternate operation are provided with line blinds or valves.



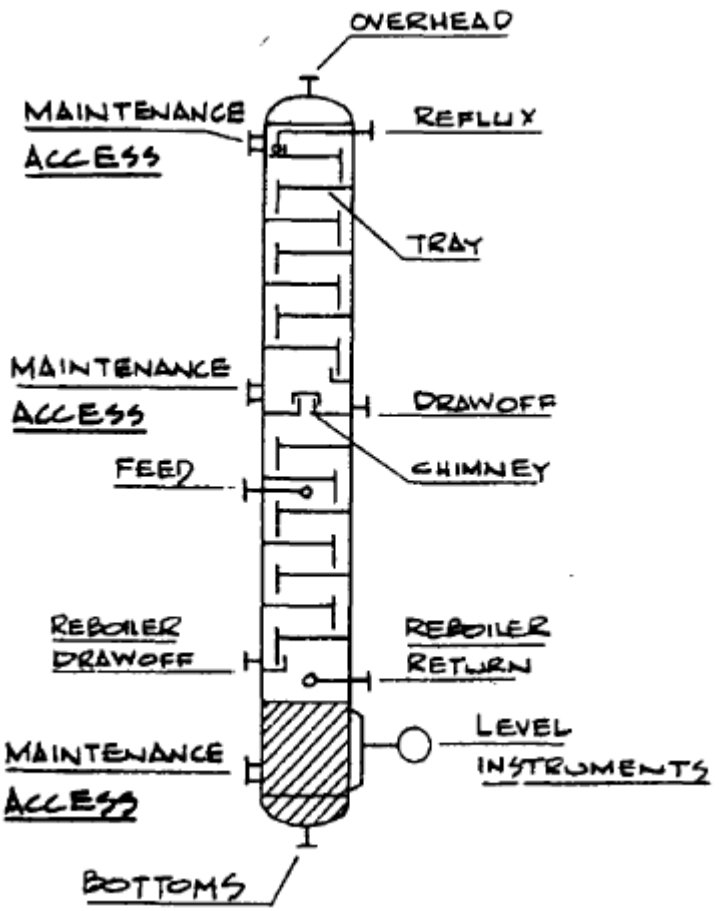
The fractionation column comprises a vertical cylinder interspaced at equal intervals with trays. Often these are in the form of simple perforated disks, but more complex arrangements occur depending upon column function. Contents are heated near the bottom producing vapors, which rise up through the trays, meeting a flow of liquid passing down as a result of condensation occurring at various levels.
It is essential to ensure maximum surface contact between vapor and liquid. The lightest fractions are drawn from the highest elevations, the heaviest residue being deposited at the bottom.

Based on internals construction there is two main common types of towers.

i. Trayed Tower
ii. Packed Tower

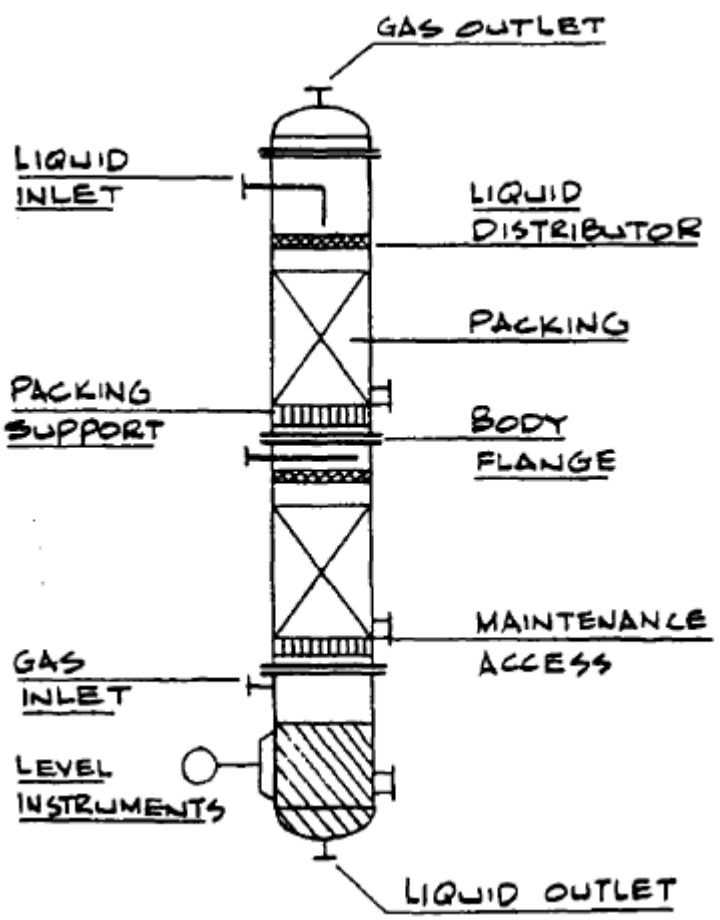
Trayed Tower:-

Example of Trayed Tower is illustrated in the fig below. Slots & holes are provided in the tray through which vapor rises & liquid flows down in this manner vapor & liquid comes in contact with each other. Low boiling fraction of the down coming liquids get vaporized by the rising vapor, the heavier boiling fraction of the rising vapor get condensed and flows downward. This continuous process of vaporizing & condensing leads to the separation of feed into required boiling range.

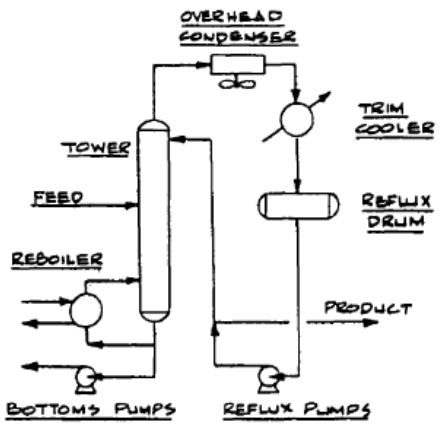


Packed Tower

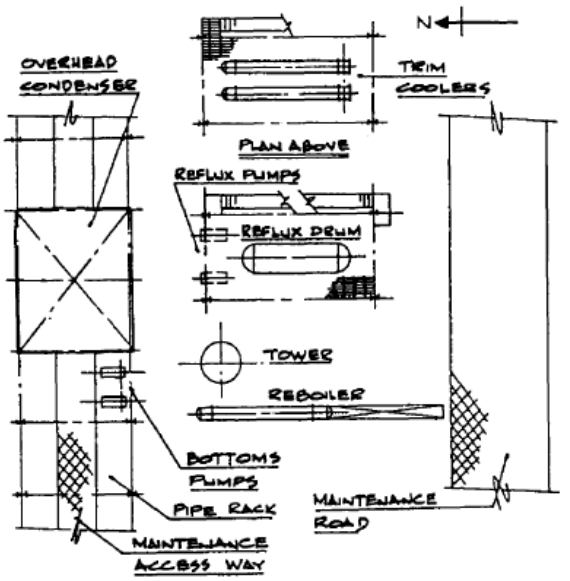
In this type the tower is packed with the bed of metal rings. liquid is made to pass evenly through the packed metal rings .the rising vapor comes in contact down coming liquid .in the manner similar to trayed tower the liquid is partially vaporized by the heat of vapor & vapor are condensed by the liquid. The fig below illustrate a typical packed tower.



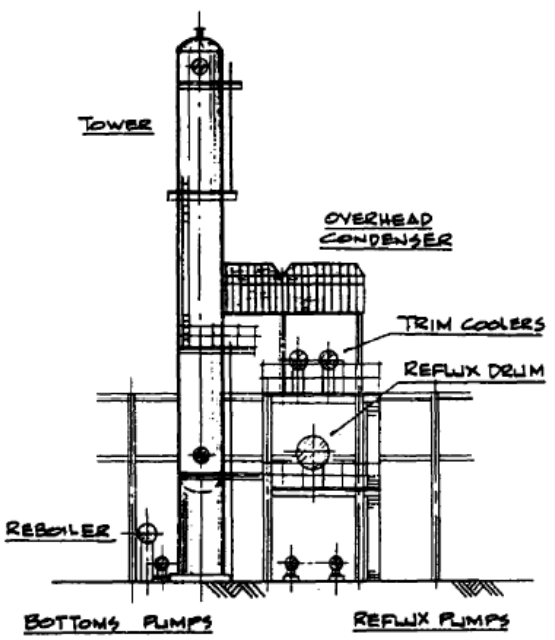
LAYOUT



a. Process Flow Diagram



b. Plan Arrangement



c. Elevation

It is necessary to establish whether column is working as a single unit or in conjunction with others similar. Dependent upon process arrangements flow may be sequential from one to the next. Thus for

maximum economy order of columns must be arranged to give shortest piping runs and lowest pumping losses. Consideration should be given, where necessary, to material used, since although correct sequence may have been effected unnecessary expense may be involved with alloy lines. Such cases must be treated on their merits.
Column is interconnected with other process equipment so it must be located adjacent to pipe rack to allow piping connections to run to and from the rack in orderly fashion. Automatically this means that man ways (provided for erection of trays and maintenance) should be located on the opposite side of the column away from the rack to provide suitable access for equipment required to be removed.

INTERNALS
Having located man ways, orientate internal trays to ensure unimpeded access. Depending upon the type of tray used one or more downcomer partitions may be required. If these are orientated incorrectly entry will be impossible via manhole unless the column is exceptionally large. Preferably downcomers are arranged normal to man way access center line. Process connections can be located in logical sequence, starting from the top when tray orientation is established.

Overheads
Highest connection is the overhead vapor line, which is usually connected to a condensing unit. An air fin type unit may be located on top of the pipe rack. Alternatively a shell and tube exchanger type condenser is usually located on a structure adjacent to the column (as may air fin unit).
Overhead vapor connection may project vertically from top of the column followed by a 90° bend or it may emerge from the side at 45°, using an integral projection extending up almost to the center top inside the head
The latter is more economic in piping since it eliminates use of some expensive fittings especially when large diameter overhead lines are involved. It also makes piping supporting simpler as use of a 45° elbow enables pipe to run down close to the column. Disadvantage is greater rigidity making stress analysis more difficult.
Often permitted pressure drop between outlet nozzle and exchanger is low (i.e. approximately 0.5 PSI) thus it is essential to obtain straightest and shortest run possible. If connection is from the top special arrangements must be made for supporting the line which is often large diameter.
The condenser is usually self draining. Often some of the condensed liquid is required to be pumped back into the column (reflux). Thus the condensed liquid flows by gravity to a reflux drum situated immediately below the exchanger. This drum can also be mounted in the same structure supporting the exchanger. This is important since if it were located elsewhere an additional pump would be required if the liquid had to be elevated again after flowing from the condenser.
Furthermore, since the liquid in the reflux drum has to be returned to the column by a pump it is convenient to locate this underneath the reflux drum at the base of the structure.
It follows, therefore, that the orientation of the outlet of the vapor connection will automatically fix the location of the exchanger and the reflux drum or vice-versa. The reflux pump discharges back into the tower usually at a high elevation, and since the piping should be straight and as short as possible, it will probably come up at the side as the vapor connection.

Reflux
Trays are numbered starting from the top. The first downcomer is therefore an odd one. Often the reflux connection is located above the top tray . This means that orientation of the odd and even trays can be

fixed since to utilize the tray contact surface, the reflux connection must occur on the opposite side of the downcomer.

Feeds

The most important connections are the feeds (see figures 4 and 6). These may occur over the odd or even trays or a combination of both. Their elevational location is entirely a function of process design. Depending upon this, orientation of the nozzle will follow, but ensure that the nozzle is not located behind the downcomer from the tray above. This would result in a liquid build up in the downcomer restricting flow through the tray below and preventing correct operation.

Feed connections are usually located in the tray area between the downcomers in a manner to ensure maximum use of the tray area as possible. Often an internal feed pipe or sparger is used to facilitate this.

Instruments

Instrument connections must be arranged so that pressure connections are in the vapor space and temperature connections are immersed in the liquid.

Sometimes it is better to put the temperature connections in the downcomer part of the tray since the depth of liquid will be greater and it will be easier to obtain effective coverage.

Probe length and mechanical interference may prevent this, if so locate thermowell over the tray itself. This should be done only on installations where the liquid depth on the tray is sufficient

The base of the tower contains a level of liquid, which is controlled by high and low level controllers, liquid level alarms and level gauges. Care should be taken when orientating these instruments, that they do not obstruct access on the platform. Physical space that these instruments occupy can be excessive. Do not position immediately adjacent to ladders or manholes.

Reboiler Connection

Reboiler liquid and vapor connections are located either relevant to liquid head (elevation) or stress requirements, or both. Two configurations are possible:

Vertical

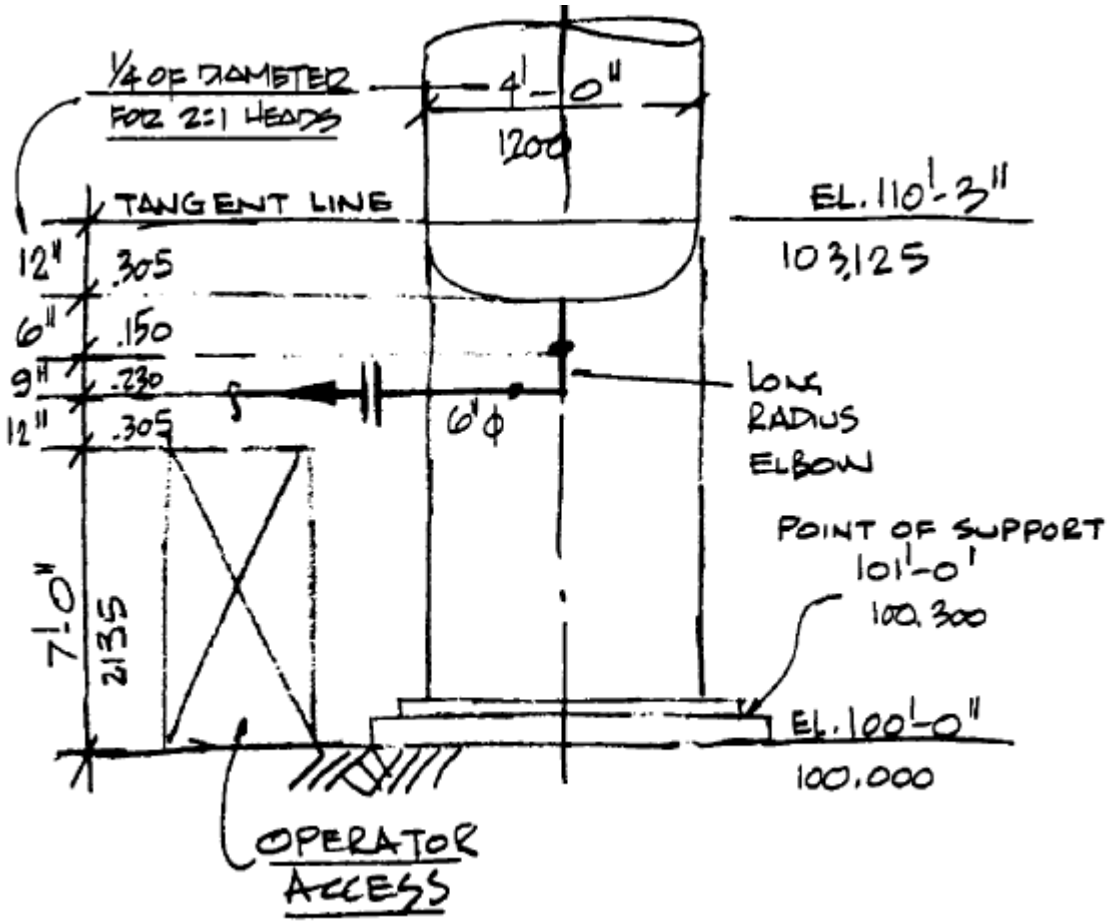
Horizontal

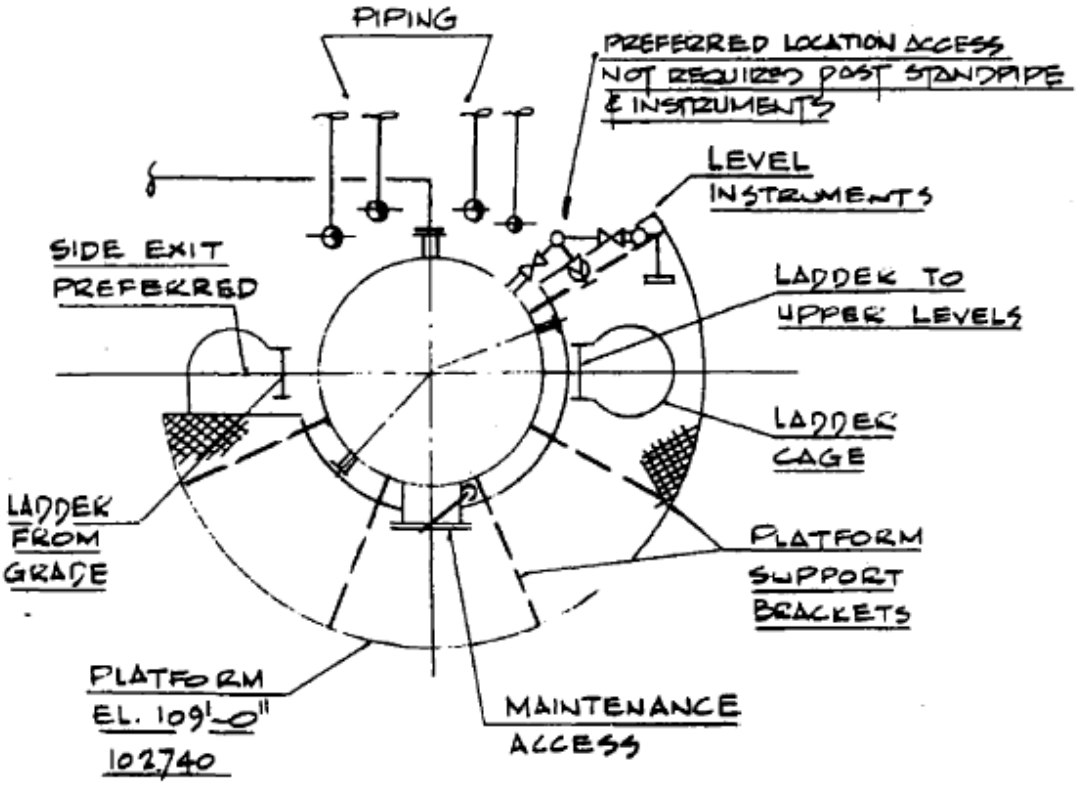
For horizontal reboilers, consideration must be given to shortest most direct connection route to reduce pressure drop, which will probably govern design layout. In both cases there may be support problems. Usually, a vertical reboiler (thermosyphon operated) offers the easiest solution.

Flexibility is obtained on the lower connection where entry into the bottom of the tower can be varied as required and support problems are simplified.

TOWER ELEVATION

+





PLATFORM LADDER ARRANGEMENT

All of the above requires access of some kind. To minimize cost minimum platforming should be provided consistent with safety.
Orientation arrangements should be designed to avoid need for 360° platforms.
A platform should not extend almost entirely round the column simply to provide access to a temperature connection, which could have been located on the oposite side. Where several columns may be working together, link platforms may be required to move from one to the next. In these cases strict consideration must be given to maximize economy.
Overall height is governed by

a. number of trays,
b. pump NPSH requirements and,
c. *static liquid head. This latter head necessary for thermosyphon reboiler establishes the skirt height.*

General Notes

- Platforms on towers are required for access to valves, instruments, blinds and maintenance accesses. Platforms are normally circular and supported by brackets attached to the side of the tower. Generally, access to platforms is by ladder.

- Platform elevations for towers are set by the items that require operation and maintenance. The maximum ladder run should not exceed 7m.

- Platform widths are dictated by operator access. The clear space on platform width shall be min.900mm.

- For platforms with control stations, the width of platform shall be 900mm plus the width of control station.

- The platform for manholes and maintenance access, adequate space for swing the cover flange flange must be provided.

- Top-head platforms for access to vents, instruments and relief valves are supported on head by trunions.

- Access between towers may be connected by common platforming.

PIPING

Some circumstances require routing lines partially around the column. Should these lines cross a platform sufficient headroom clearance must be provided.

TOP HEAD RELIEF VALVE

Relief valves vary in number and size. Location can depend on whether discharge is to atmosphere or a closed system. If discharging to a closed system, locate at a convenient platform down the column above the relief header If discharging to atmosphere locate on top of the column, with the open end of the discharge a minimum of 3000 mm above the top platform. For maintenance removal, valve should be located to allow top head davit to pick it up. Dependent upon size multiple relief valves may require a gantry structure on the top head.

CLIPS

Early orientation of nozzles and routing of lines allow platforms and pipe support clip locations to be passed to column vendor quickly.

It is becoming more a requirement that clips be welded on in the vessel fabrication shop particularly for alloy steels.

When locating platforms and ladders, the maximum ladder length should not exceed 9M without a rest platform.

Platforms should, where possible, be elevated 900 mm below man ways.

Man ways Davits or hinges should be positioned to avoid swing of cover fouling instruments or other connections.

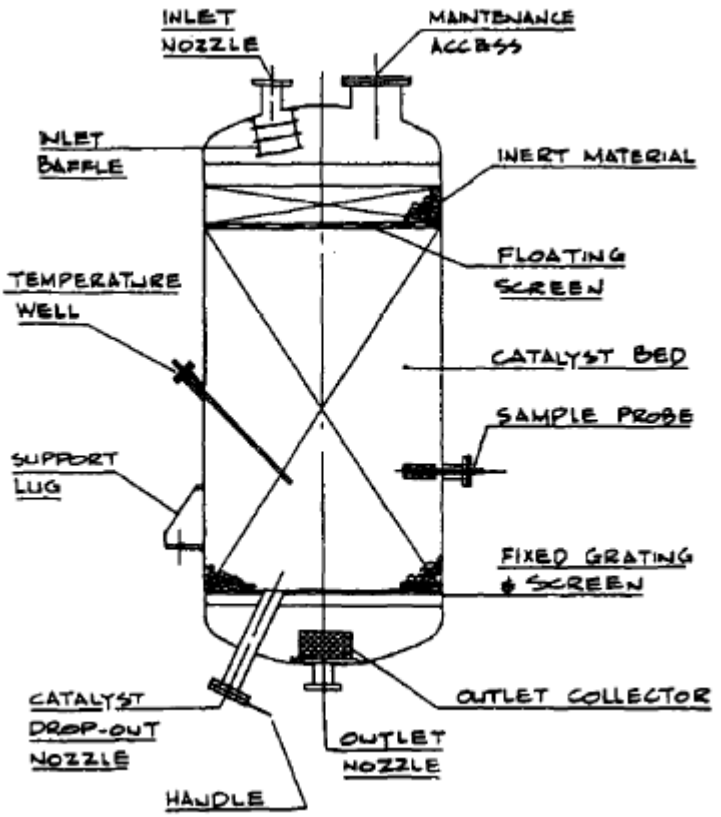
When positioning vertical piping, to simplify supporting, attain a common back of pipe dimension from column shell of 300 mm

PIPING STUDY
REACTOR PIPING

INTRODUCTION

Reactors are usually a vertical equipment where various chemical reaction takes place. Very often reactors are having agitators mounted either on top or bottom of the vessel. Reactors may have external jacket or internal coil for any heat transfer requirements.

Reactors with agitator, gearbox and motor arrangement make the assembly heavy and vibrating.

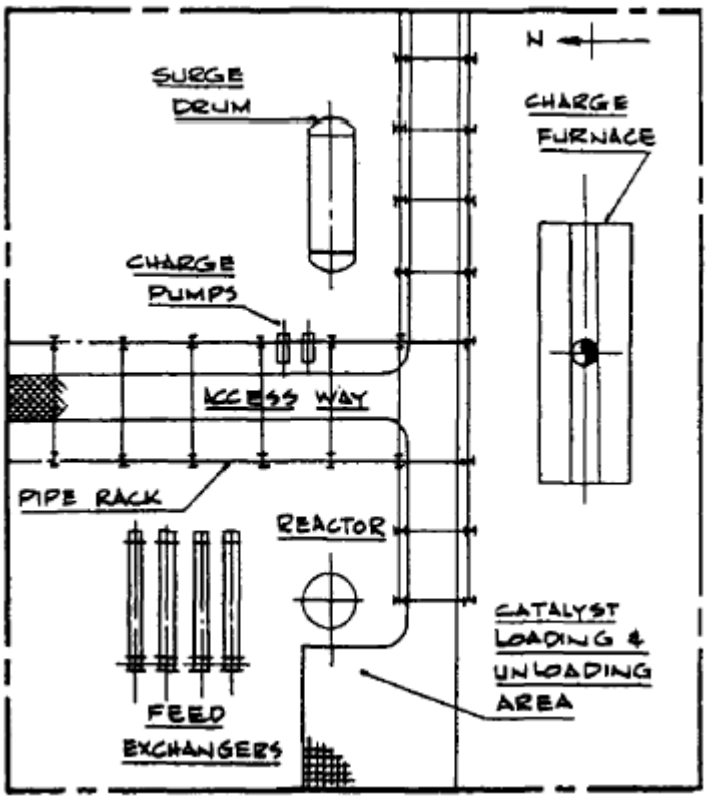


TYPES OF REACTOR

There are various types of reactors in chemical, fertilizer and refinery plants viz. Batch reactors, Fixed-Bed Reactors, Gas-Fluidized Bed Reactors. Based on the process function, they are called as Desulphurisers, Convertors, Hydrotreaters etc. This piping study is also applicable for equipment called crystallizers, evaporators, thickners etc.

LOCATION

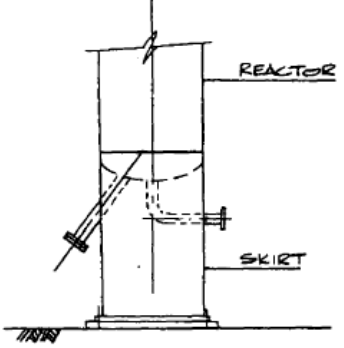
Reactors are located within a process unit adjacent to related equipment with the facilities for catalyst loading and unloading as well as close to furnace to minimize expensive high-temperature piping.



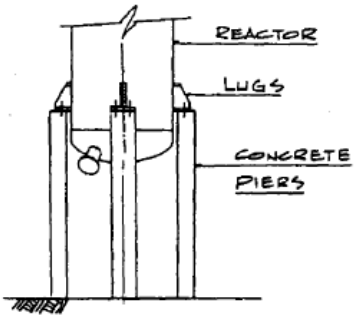
SUPPORT

Reactors are generally supported by following four methods.

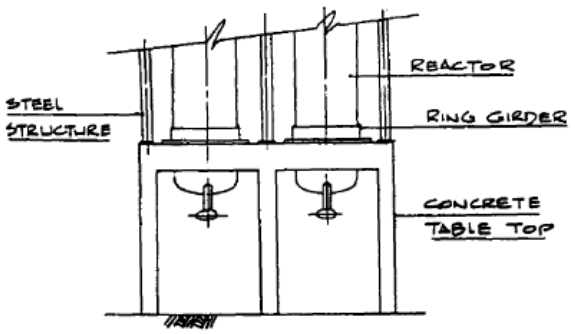
i. Skirt from a concrete foundation.
ii. Skirt from a concrete table top.
iii. Lugs from concrete piers .
iv. Ring girder from concrete table top.



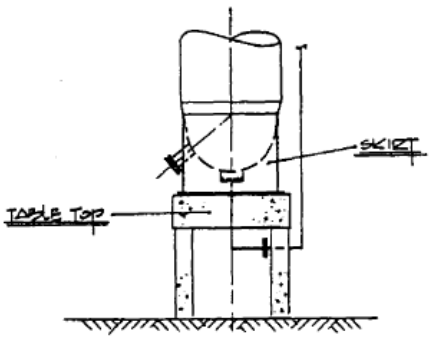
a. Skirt Supported (Foundation)



b. Lug Supported



c. Ring Girder Supported

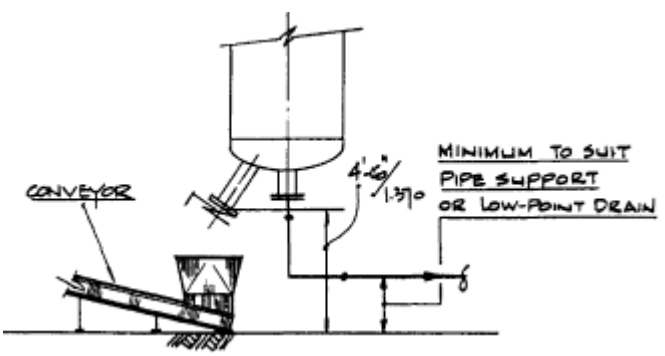


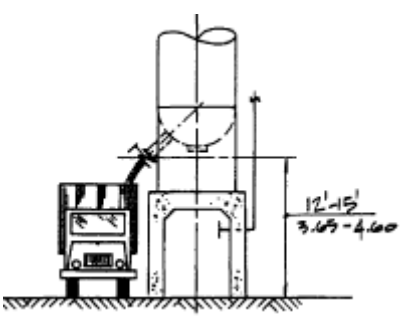
d. Skirt Supported (Table Top)

ELEVATION

Reactor elevation is dictated by following factor

i. Overall dimension of reactor.
ii. Type of reactor head.
iii. Type of reactor support.
iv. Size of bottom nozzle.
v. Size of unloading nozzle.
vi. Type of catalyst handling.





PLATFORM ARRANGEMENT

- Platforms are required for access to valves, instruments, blinds maintenance access, feed openings etc.

- Platform elevations are determined by the items that require operation and maintenance and on tall reactors platform elevations are set to accommodate a maximum ladder run of 9m.

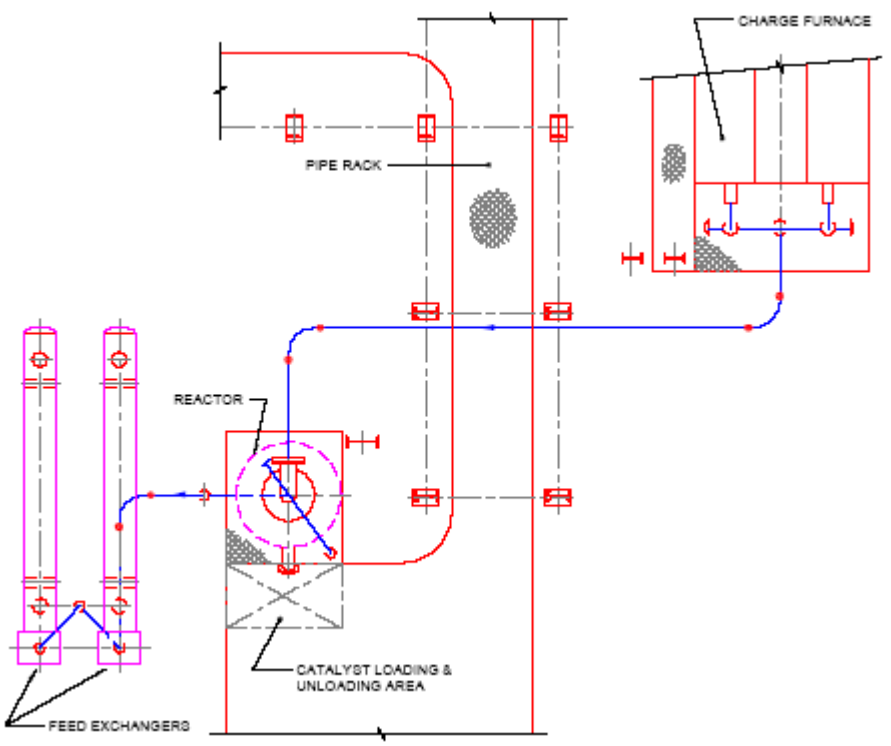
- Reactors taller than 9m shall be treated like towers for platform requirements. In case of Reactors, intermediate platforms and ladders are required only for access to temperature instruments, sample probes, catalyst unloading nozzles and maximum ladder runs.

PIPING ARRANGEMENT

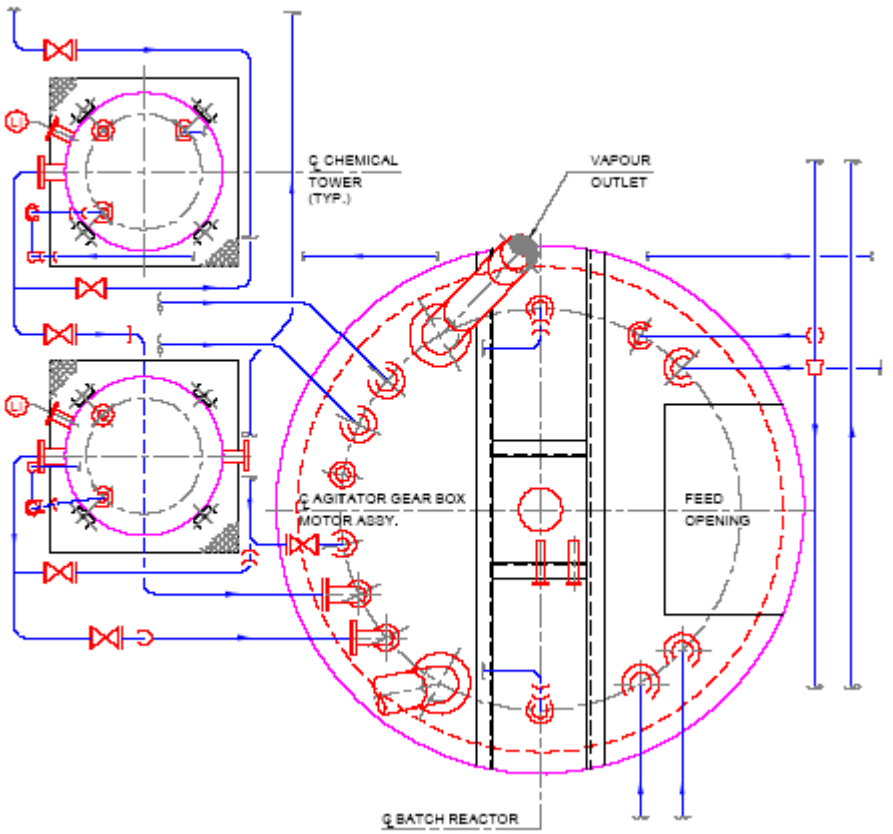
- The reactor Piping should run in group & on common BOP for the ease of supporting.

- Reactor generally operates at high temperature, hence piping should be routed with sufficient flexibility to reduce stress & nozzle load.

- A simple example of reactor used in refinery plants is illustrated in the fig below.

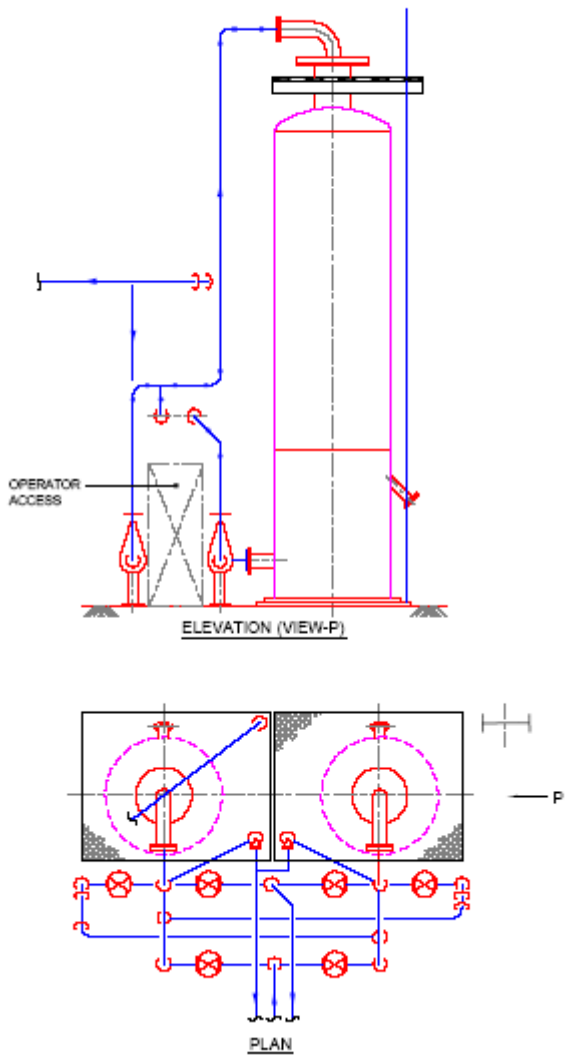


- A simple example of reactor used in chemical plants is illustrated in the fig below. Nozzles are arranged around the outer zone of reactor opposites to feed opening. The central zone is occupied by agitator, gear box & gear mountings.

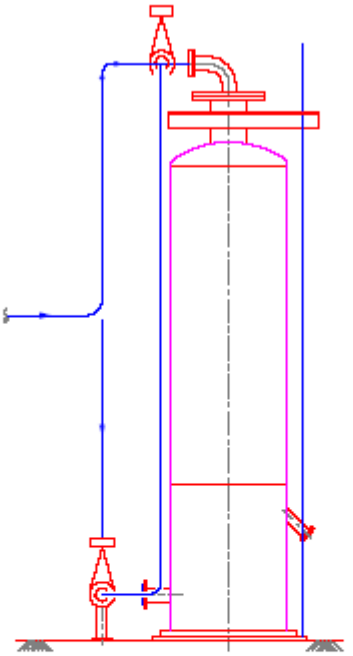


- If the reactors are arranged in series ,the manually operated valves manifold are generally placed on the grade, & if the valve are remotely operated then valve manifold can be placed on top platform of reactors. It is illustrated in the below fig

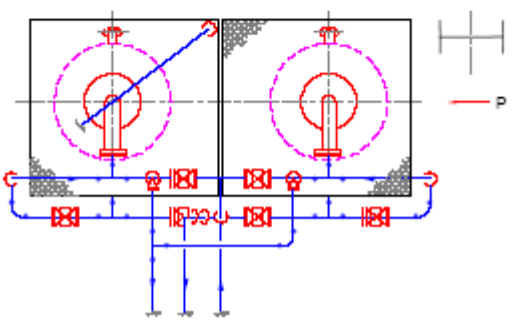
REACTORS IN SERIES: MANUALLY OPERATED VALVE MANIFOLD



REACTORS IN SERIES: REMOTELY OPERATED VALVE MANIFOLD

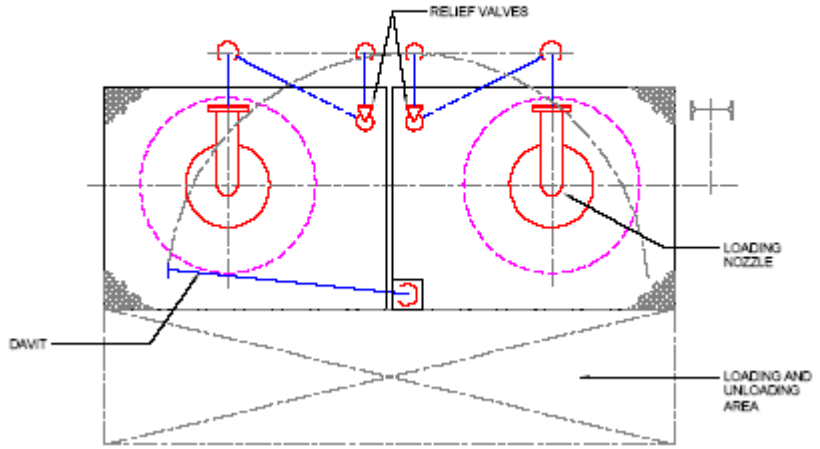


ELEVATION(VIEW-P)

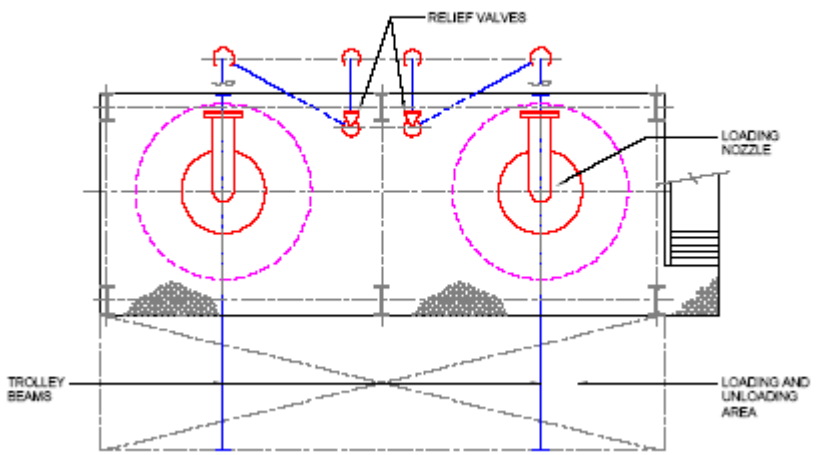


PLAN

DAVIT ARRANGEMENT ON REACTOR TOP



TROLLEY BEAM ARRANGEMENT ON REACTOR TOP



PIPING STUDY
STORAGE TANK
TANK FARM

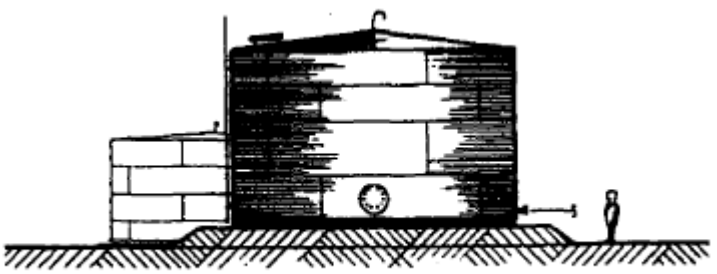
INTRODUCTION

Tank farm :- Storage tanks located in a safe area and grouped according to the contents are called tank farm. Normally, in chemical plants, the storage shall be either input raw material or output products or intermediate chemicals storage.
Storage tanks may contain acids, alkalis; oil viz. petrol, diesel, naphtha, fuel oil or benzene etc. Oil, acid, alkali is usually stored in vertical storage tanks designed as per API 650.

Dyke - A dyke is a barrier designed to contain liquid in the tank in case of emergency within the area for safety reasons.
The dyke may be constructed of earth, concrete, solid masonry or steel. It may be square, rectangular, circular or irregular in shape, conforming to the natural terrain around the tank.

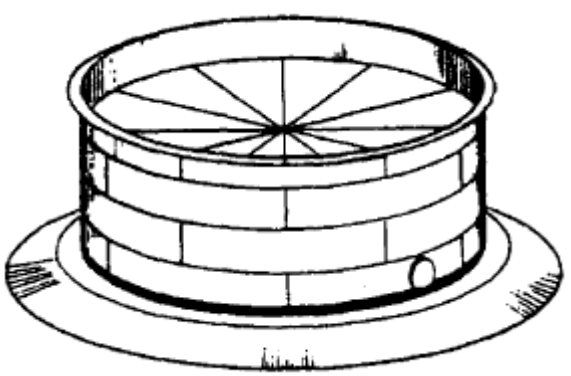
TYPES OF TANKS.

i. Cone roof Tank :-



This is a low-pressure vertical storage tank with a cone-shaped fixed roof.

ii. ***Floating roof Tank :-***

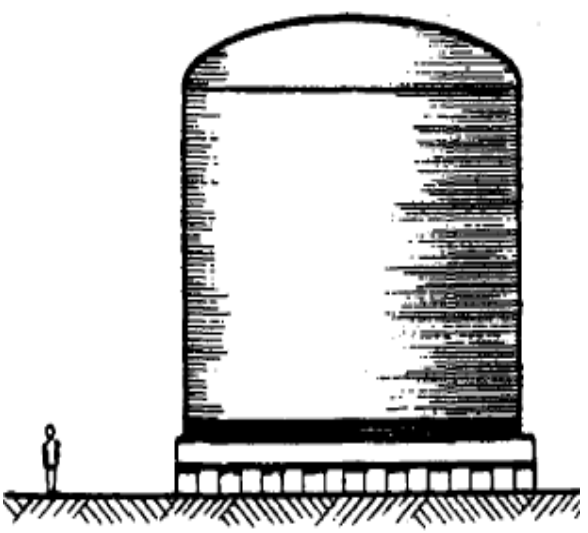


The roof of the tank rises & lowers with the contents inside, thereby reducing the vapor loss & minimizing fire hazard.

iii. ***Bullet Tank :***

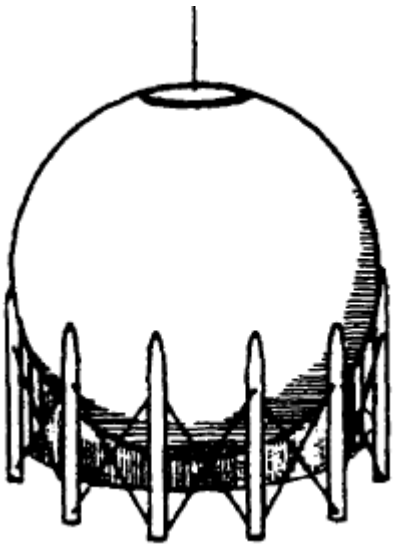
This is a high pressure horizontal storage vessel shaped like a bullet

iv. Low temperature storage tank:-



This tang stores liquefied gases at their boiling point

v. ***Hortonsphere pressure tank:-***



This type of tank is used to store large quantities of liquids & gases under pressure.

TERMINOLOGY

- **Atmospheric Tank :-** *This is the tank, which operates at atmospheric pressure to 0.5 psi.*

- ***Barrel :-*** This is a standard unit of liquid volume in petroleum industry that is equal to 42 US gallon at 60°F

- ***D*yke** :- This is the barrier designed to contain the spillage from tank within a given area for safety reason.

CLASSIFICATION OF PETROLEUM PRODUCT

CLASS-A	Liquids which have flash point less than 23°C
CLASS - B	Liquids which have flash point 23°C & above but less than 65°C
CLASS - C	Liquids which have flash point 65°C & above but less than 93°C
EXCLUDED	Liquids which have flash point above 93°C

REGULATORY QUANTITY ABOVE WHICH LICENCE IS NECESSARY

CLASS-A	30 liters
CLASS - B	2500 liters
CLASS - C	45,000 liters

API TANK SIZE - FOR LAYOUT PURPOSE

Based on API650

Capacity Approximately		**Diameter**	**Height**
US Barrels	**CU Meters**	**Meters**	**Meters**
500	75	4.6	4.9
1.000	150	6.4	4.9
1.500	225	6.4	7.3
2.000	300	7.6	7.3
3.000	450	9.2	7.3

4.000	600	9.2	9.3
5.000	750	9.2	12.2
6.000	900	9.2	14.6
7.000	1050	12.2	9.9
9.000	1350	12.2	12.2
10.000	1500	12.8	12.2
12.000	1800	12.8	14.6
15.000	2250	14.6	14.6
20.000	3000	18.3	12.2
30.000	4500	22.3	12.2
40.000	6000	26.0	12.2
50.000	7500	27.5	14.6
90.000	12000	36.6	12.2
100.000	15000	41.0	12.2
120.000	18000	41.0	14.6
140.000	21000	49.8	12.2
180.000	27000	54.9	12.2
200.000	30000	54.9	14.6
300.000	45000	61.0	17.0
450.000	60000	73.2	17.0
600.000	90000	91.5	14.6
800.000	100000	105.0	14.6

LAY OUT CONSIDERATION FOR EXPLOSIVE TANK FARM

- Tank farm should be designed & planned according to the CCE rules and regulations. CCE rules are applicable to the fluids of petroleum and petroleum products classified as class A, B or C according to its flash point characteristics.

- The rules of CCE can be followed for other hazardous / inflammable products as good guidelines of safety, even though the product is not classified as petroleum product.

- Petroleum storage tank should be located inside the dyked enclosure.

- Suitable roadways should be provided for approach to tank sites by mobile fire fighting equipment and personnel.

- In case of emergency the dyke enclosure should be able to contain the complete spillage of the largest tank. Enclosure capacity is calculated after deducting the volume of tanks other than the largest tank. Up to the height of dyke. A free board of 200 mm shall be considered for fixing the height of dykewall.

- Height of enclosure should not be less than 1M & more than 2M . For excluded class it can be 600mm .

- The slope on the surface of dyke is usually 1:1.5 consistent with the angle of repose of earth.

- Class A & class B Petroleum can be stored in the same dyke enclosure. If class C is stored together all safety stipulation applicable classA/classB shall apply.

- Excluded class should be arranging in the same dyke .

- For reasons of fire fighting access there should be no more than two rows of tanks between adjacent access roads.

- Tank height should not exceed 1.5D of tank or 20M whichever is less.

- Minimum distance between tank shell & dyke wall should not be less than 0.5D of tank.

- Fixed roof with internal floating covers should be treated for spacing purposes as fixed roof tanks.

- Where fixed roof and floating roof tanks are adjacent, spacing should be on the basis of the tank(s) with the most stringent conditions.

- There should be at least two access point on opposite side of bund for safe access.

- Tank farms should preferably not be located at higher levels than process units in the same catchments area.

- The fire water system should be laid out to provide adequate fire protection to all parts of the storage area and the transfer facilities.

- All drains from the dyke area should be equipped with a valve outside the dyke regardless of whether the drainage goes to disposal pit or sewer system. This prevents liquid spillage from entering the sewer or released from the dyke area.

LAY OUT CONSIDERATION FOR EXPLOSIVE TANK FARM

- Storage vessel is installed always above the ground , never underground .

- Vessel should be located in an open area .

- Vessel should not be installed one above other, vertically.
- If vessels are more than one, the longitudinal axis should be parallel to each other.
- Top surface of all vessels should be in one plane .
- Vessels arranged with their dish end facing each other should have screen between them.
- Tank farm area should be enclosed by industrial type fence at least 2m high all along the perimeter.

Minimum safety distance for flammable ,corrosive & toxic gases.

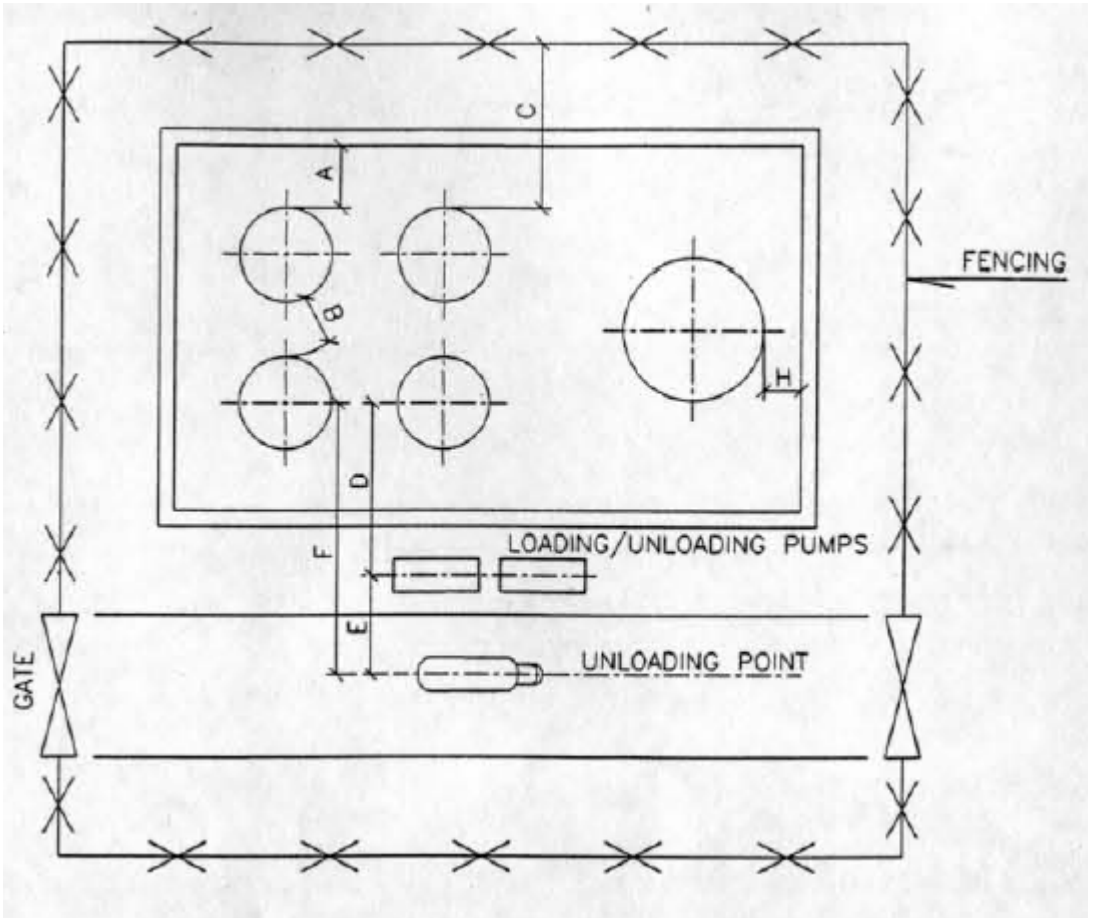
S/N	WATER CAPACITY OF VESSEL(in Liters)	MIN DISTANCE FROM BUILDINGS	MIN DISTANCE FROM PRESSURE VESSEL
1	Not above 2000	5 Meters	1 Meters
2	Above 2000 but less than 10,000	10 Meters	1 Meters
3	Above 10,000 but less than 20,000	15 Meters	1.5 Meters
4	Above 20,000 but less than 40,000	20 Meters	2 Meters
5	Above 40,000	30 Meters	2 Meters

Minimum safety distance for non- toxic gases.

S/N	WATER CAPACITY OF VESSEL(in Liters)	MIN DISTANCE FROM BUILDINGS	MIN DISTANCE FROM PRESSURE VESSEL
1	Not above 2000	3 Meters	1 Meters
2	Above 2000 but less than 10,000	5 Meters	1.5 Meters
3	Above 10,000 but less than 20,000	10 Meters	2 Meters
4	Above 20,000 but less than 40,000	15 Meters	Dia of larger vessel

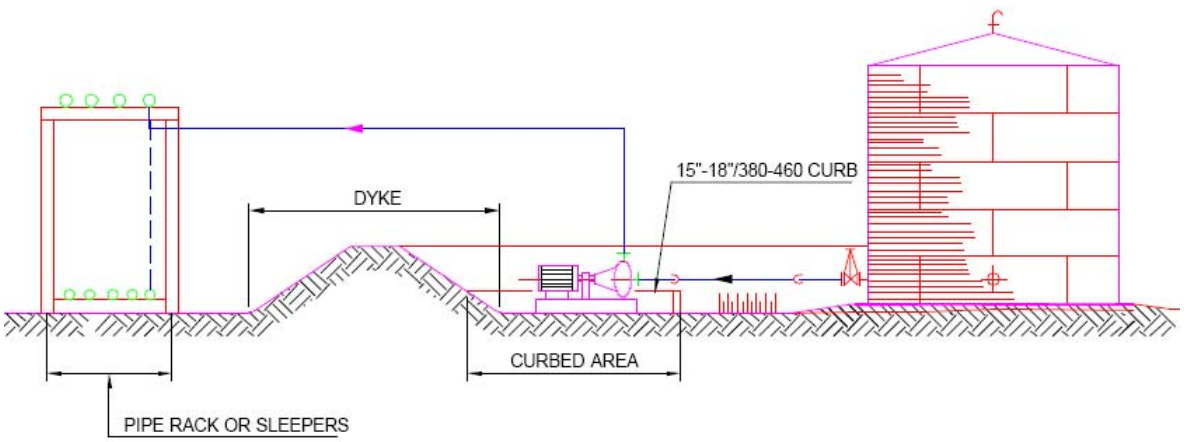
Minimum clearance to considered as per OISD guidelines.

1	Storage tanks class A/B	0.5D or 15M for class A/B 6M for class C
2	Storage tank to vehicle unloading	15M for class A/B 6M for class C
3	Vehicle unloading to boundary fencing	15M for class A/B 3M for class C
4	Storage tank periphery to boundary facing	15M for class A/B 4.5M for class


C
A
B
H
D
F
E
FENCING
LOADING/UNLOADING PUMPS
UNLOADING POINT
GATE

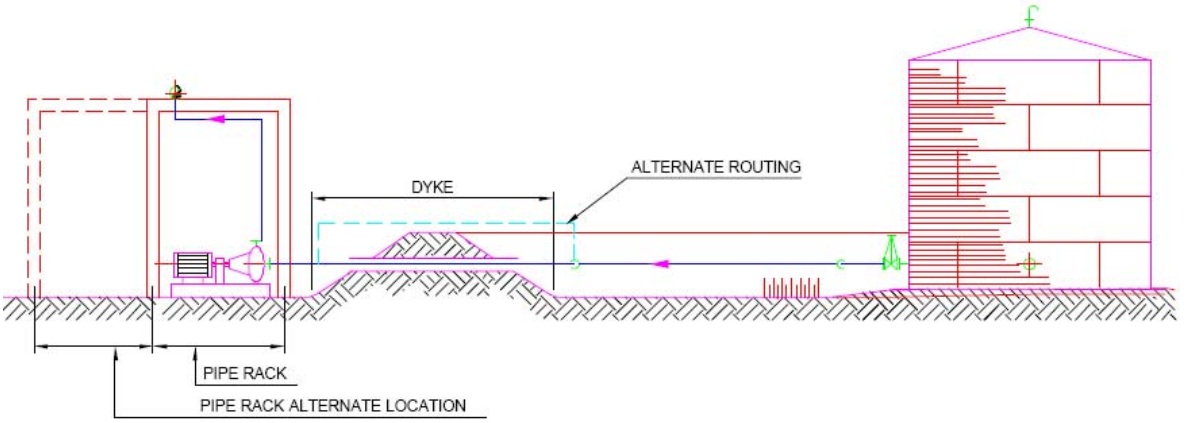
PUMP LOCATION IN TANKFARM

- To determine the optimum location of pumps, the potential hazards and client preference shall be considered.
- Fig. Below illustrates the location of pump within the dyke area with the curb wall height of approx. 400-500mm. This design protects the pump from minor spillage within the dyke and enable the discharge piping to exit the dyke over the wall and there is no need to have dyke penetration seals. The piping outside the dyke may run on a pipe rack or sleepers.



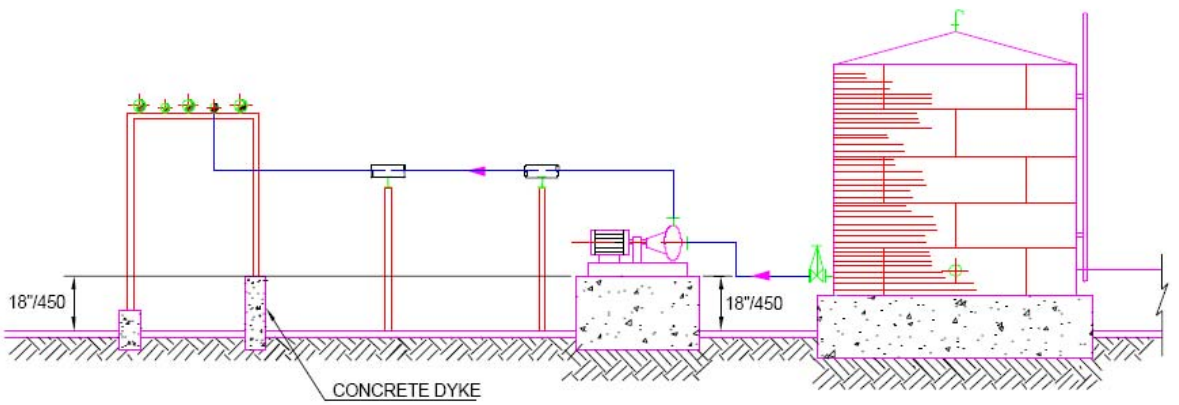
PUMP INSIDE THE DYKE

- The pumps located outside the dyke area are illustrated in Fig below .Tank outlet piping can either penetrate the dyke or pass over the dyke in case the minimum liquid level in the tank do cause cavitations in the pump.

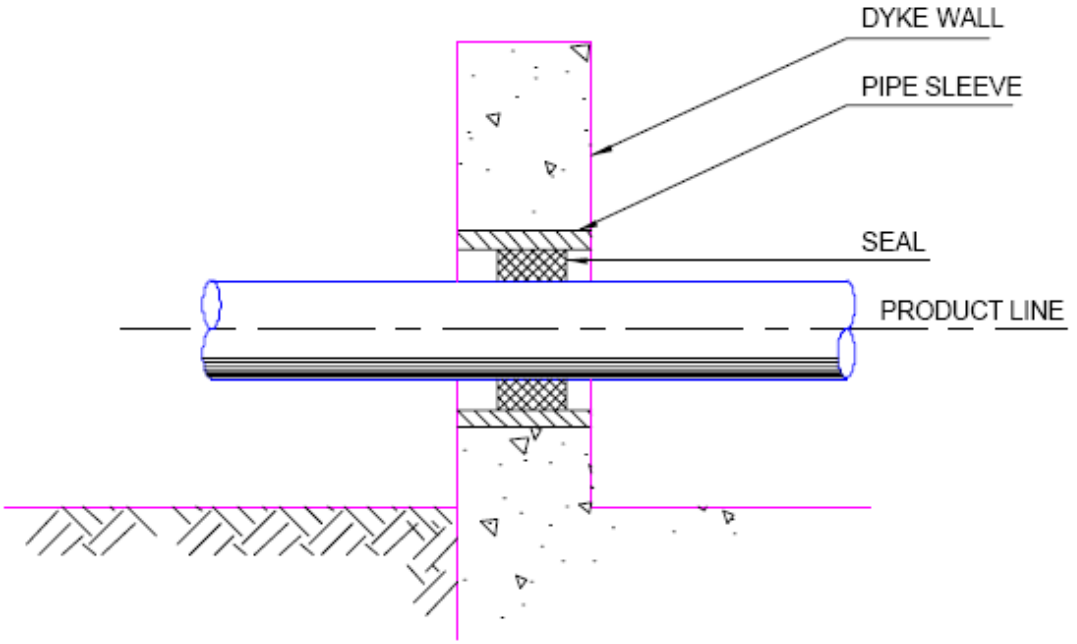


PUMP OUTSIDE THE DYKE

- Adequate maintenance area around the pump shall be the prime consideration for planning the piping arrangement at suction as well as discharge.



PUMP INSIDE THE CONCRETE DYKEWALL



DYK PENETRATION SEAL

PIPING ARRANGEMENT

- The Optimum piping arrangement in a tank farm is the most direct route between two points allowing for normal line expansion and stresses. Fig below shows how to accommodate line expansion between tank nozzles and a manifold header. Expansion loops may be added at the sleeper level.

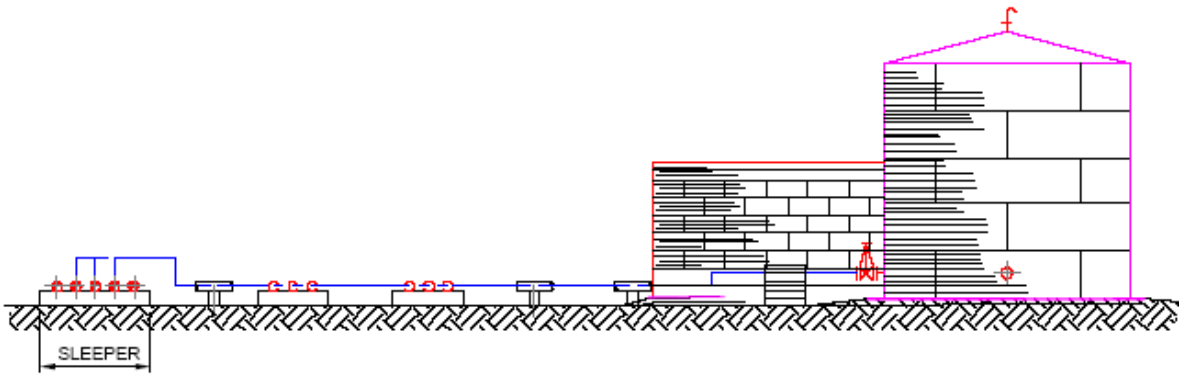
- Tanks are installed at the lowest possible elevation to satisfy the pump head requirements. A catwalk is usually located across all the tanks in a row to provide access to the operating valves and instruments.
- Liquid outlet piping to the suction of Pump shall allow for differential settlement and the flexibility of the piping.

- In addition to the provisions for mobile fire-fighting equipment, permanent hydrants, monitors are used for protection against fire in the tank farm areas.

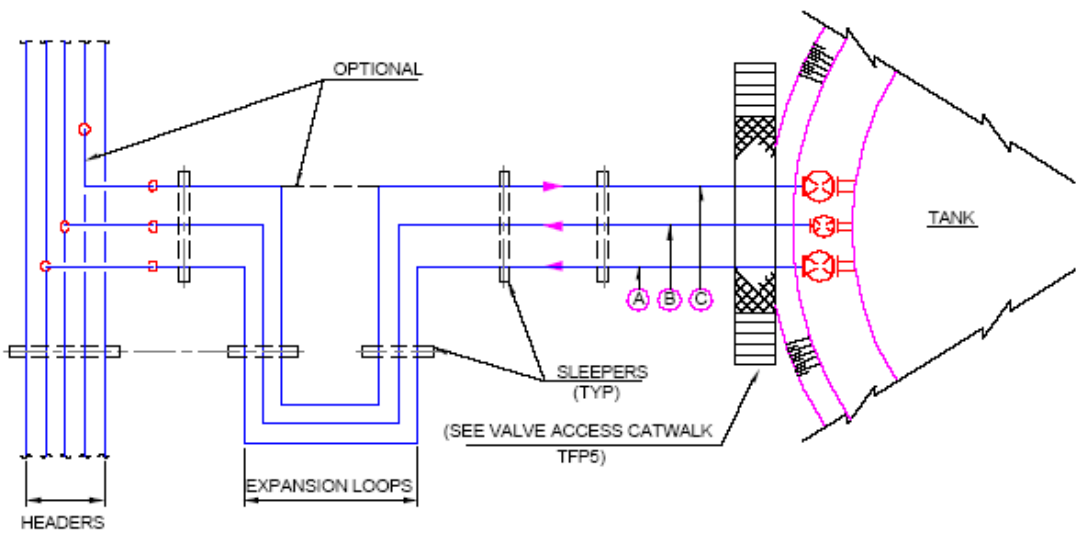
- The codes, regulations viz.CCE, TAC, NFPA shall be consulted to finalize the safety requirement of the tank farm.

- The sump and sump pump shall be provided for disposal of water accumulation due to rain or firefighting.

- The foam piping shall be arranged with the quick coupling to the line supply to the foam chamber at the edge of the roof of the tank. The coupling shall be located outside the dyke wall.



ELEVATION



PLAN

PIPING STUDY
UNDERGROUND PIPING

INTRODUCTION

The term "underground" applies to the piping - both **buried** or in **trenches.**
The underground system consist of gravity flow drainage system carrying process waste, spillage, reclaimable hydrocarbons, sanitary and storm water, firewater and drinking water & utilities line normally 18" & above.

The following are the common underground services in a chemical / petrochemical / refinery plants.

- Cooling water (line size normally ≥18" NB)
- Fire Water
- Contaminated Rain Water Sewer from process catchments area.(CRWS)
- Oily Water Sewer (OWS)
- Liquid Effluent to the Effluent Treatment Plant.
- Closed Blow Down system (CBD)
- Sanitary system
- Storm Water
- Equipment drainage to slop tank
- Electrical cables
- Instrument cables

TYPES OF UNDERGROUND SYSTEM

Various underground systems can be described in the following way both for Utility system and sewer system.

i. Cooling Water System (CWS & CWR)

- This is generally a buried system with protective wrapping and coating or with cathodic protection or both.
- Any valve for isolation of a part of the cooling water system shall be enclosed in a valve pit.
- The normal compacted earth cover shall be 1200 mm over the top of the pipeline.

ii. Oily Water Sewer (OWS)

- The oily-water sever is designed to collect all non corrosive process spillage & wastes drained periodically from tanks, towers, exchangers, pumps & other process equipments using open end drain funnels located adjacent to equipment served.
- The oily –water main trunk sever flows to an oily water separator for oil removal
- Sediments are removed in sludge disposal chamber.

- Oily water sewer shall consist of carbon steel sewer, funnel points, clean outs, RCC catch basins, RCC manholes, vent pipes, flame arrestor etc.

iii. ***Contaminated Rainwater Sewer (CRWS)***

The areas which are contaminated due to floor wash drains etc. inside unit boundaries shall be demarcated. Contaminated areas collected in catch basin shall be drained through CRWS while un-contaminated areas, normally at periphery of the units shall be drained through ditches covered with grating.

CRWS shall consist of undergound carbon steel sewer with corrosion protection, funnel points, clean outs, RCC catch basins, RCC manholes, vent pipes, flame arrestor etc.

Open ditches of units should have a bypass either to the CRWS or to storm water, drains of offsite.

iv. ***Closed Blow Down (CBD) sewer***

This system collects drains around boilers and steam drums .usually it runs as a separate system

v. ***Amine Blow Down (ABD) sewer***

The effluent is collected from equipments through above ground points into close funnels connected to underground system. The main header shall be connected to the underground Amine sump / drum.

vi. ***Fire Water Sytem***

This system consists of a fire hydrant network around a process unit or equipment, with branches as required for hydrants or monitors to protect the unit in case of fire.

This is a close loop system starting from Firewater storage and pump to the specific location of hydrants and monitors. This is always kept under a predetermined working pressure level.

vii. ***Potable Water System***

This water is used for drinking, emergency eye washes and safety shower facilities.

viii. ***Sanitary Sewer System***

The sanitary sewer constitutes a separate sewer system into which waste of other than sanitary facility are not allowed. The sanitary sewer should discharge into a septic tank.

ix. ***Underground Electrical and Instrument ducts***

In the beginning of a project, the decision to route the major electrical and instrument conduits - above ground in the pipe rack or buried below grade shall be taken.

In case underground route is selected, electrical and instrument engineers shall be consulted for the optimum layout of ducts by the plant layout engineer.

associated maintenance access.

GENERAL ITEMS USED IN SEWER SYSTEM

i. ***Drain Funnels:-*** Drains funnels or hubs are usually used for above ground equipment drainage.

ii. ***Sewer box :-*** A sewer box is normally provided for surface drainage.

iii. ***Catch basin:-*** *it is used as a junction for change of direction of sewer branch lines or a change in direction*

iv. ***Man hole :-*** Man hole sewer should be installed in the sewer mains at 90 meter maximum intervals for sewer size up to 24" inch diameter & at 150 meters maximum intervals for sizes above 24". Manholes should also be installed at dead end of the sewer branch & where the diameter changes.

v. ***Seal***:- a seal consist of an elbow or tee with outlet extending downward to provide for a maximum 150 mm seal.

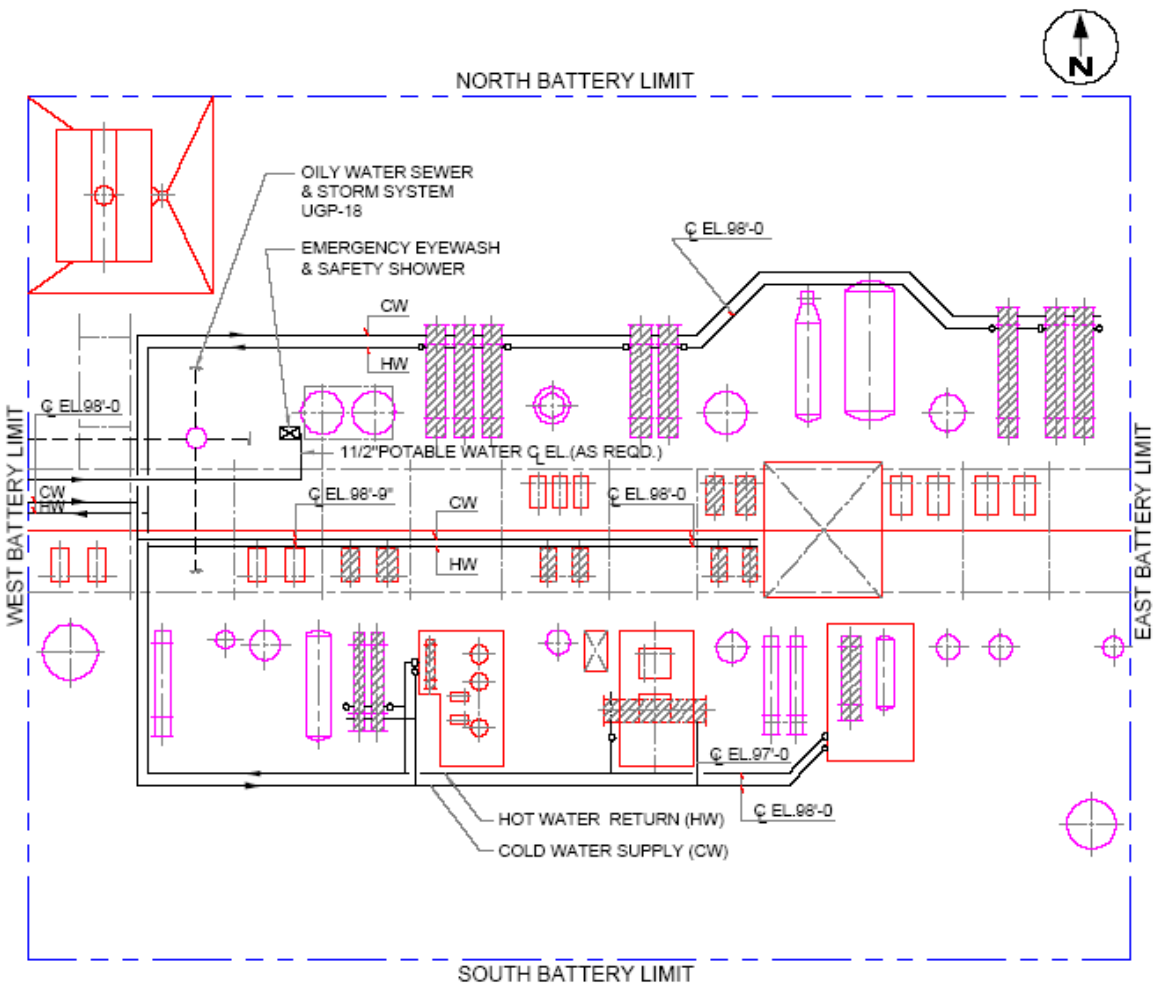
vi. ***Cleanout*** :- A cleanout is a piping connection in a sewer system that is located at grade level for inspections or for cleaning the system.

vii. ***Vent Pipes*** Vent pipes shall be located along pipe rack columns or building columns and should be taken 2m above the building parapet or last layer of pipes on a pipe rack.

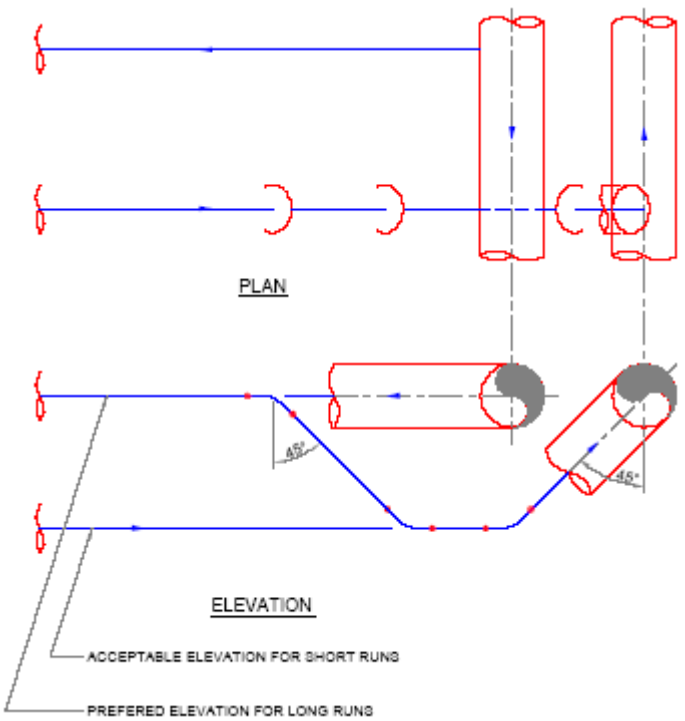
viii. ***Valve Pit / Maintenance pit for flanges and instruments.*** When the underground system needs valves for isolation and instruments for control, the normal practice is to enclose these valves and instruments in a RCC pit with cover. These valves and instruments in a pit can be operated as well as maintenance work can be done with ease.

PIPING ARRANGEMENT :-

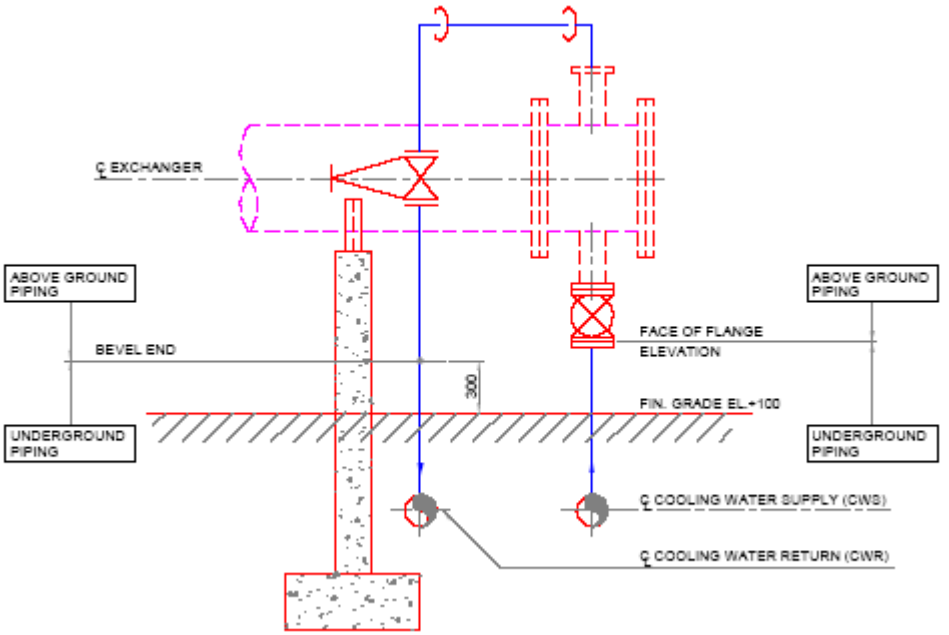
- The cooling water supply from cooling water pump discharge to the various units as well as the cooling water return from the various units to the top of cooling tower is routed in a simple, straight orientation at a suitable depth avoiding any major road crossings. A typical cooling water and potable water system is illustrated in sketch below



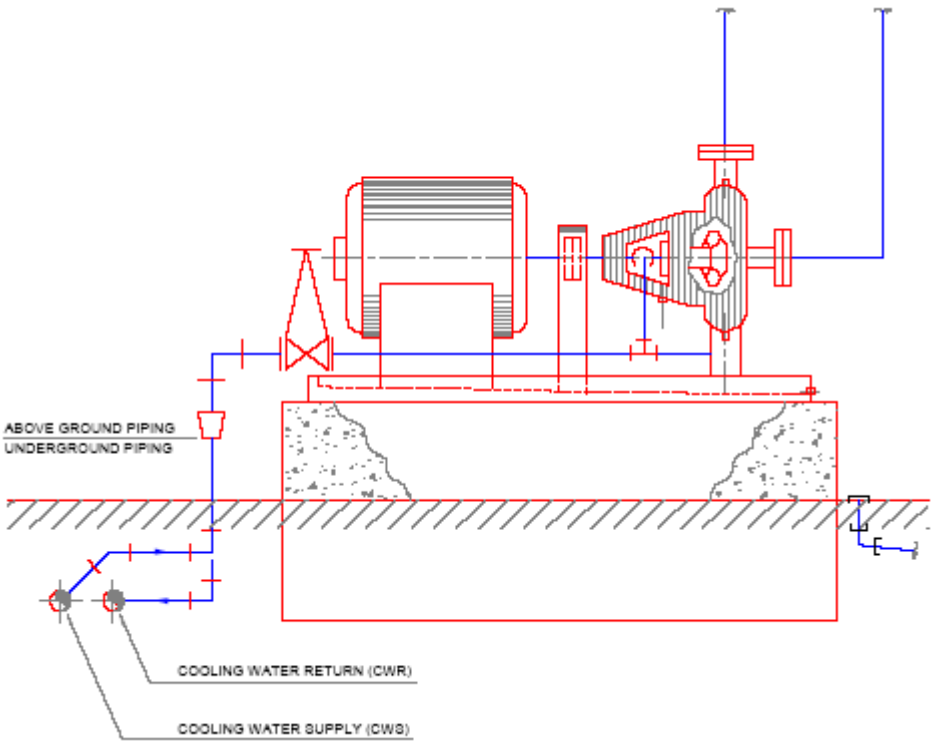
- Cooling water cross over piping is illustrated in sketch below



- Cooling water lines to heat exchangers are typically illustrated in sketch below



- Cooling water lines to pumps for various cooling requirements is illustrated in sketch below



PIPE SUPPORT

PURPOSE OF PIPE SUPPORT

- To support the weight of pipe & components during operation & testing.
- To take the load due to thermal expansion.
- To absorb vibration in the piping system.
- To take the hydraulic thrust in piping.
- To support the system during shut down condition.
- To support the system during maintenance.
- To take earthquake load.
- To take wind load.

CLASSIFICATION OF PIPE SUPPORT.

Pipe support is broadly classified as

- **Primary Support.** :- This is directly attached to the pipe.

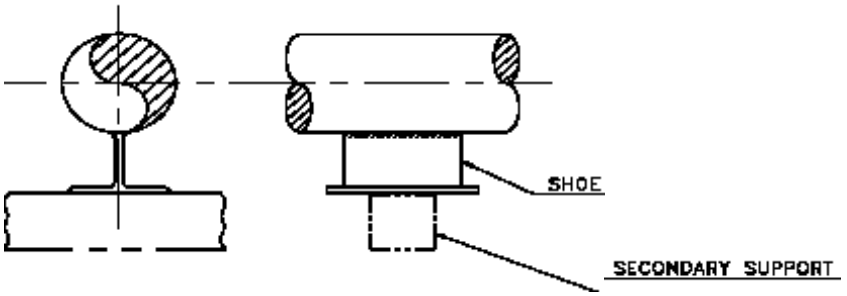
- **Secondary Support** :- This is directly attached to the structure or foundation to support the primary support.

Primary support can be of following types.

- ***Rest support*** :-

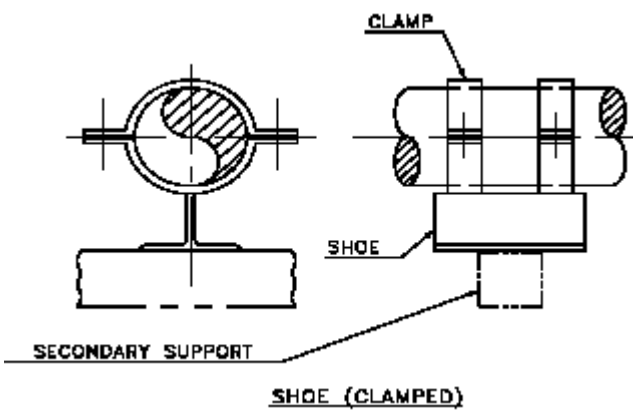
  This is most commonly used support meant for supporting only the pipe weight vertically. It allows pipe to move in axial as well as transverse direction but restricts only the vertical downward movement. Pipe simply rest on the structure.

- ***Shoe weld support:-***



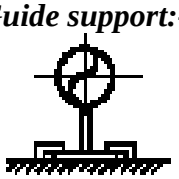
This is generally used to support insulated lines, which cannot be directly supported on steel structure. Usually a I- beam cut into two half is used as a shoe. Shoe height depends upon the insulation thickness. It allows pipe to move in
axial as well as transverse direction but restricts only the vertical downward movement. .shoe is directly welded to the pipe.

- ***Shoe clamp support:-***



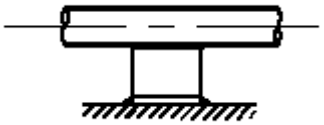
This is similar to shoe weld support. shoe is welded to a clamp put around pipe

- ***Guide support:-***



This type of support is used to restrict the movement of pipe in transverse direction i.e. perpendicular to length of pipe but allow movement in longitudinal direction. This is also a commonly used type of support.

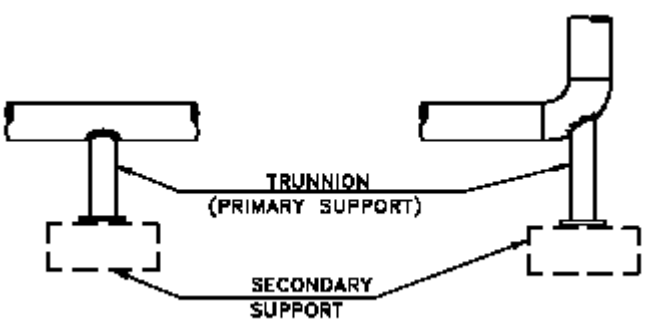
- ***Anchor support.***



This type of support is used to restrict movements in all three directions.

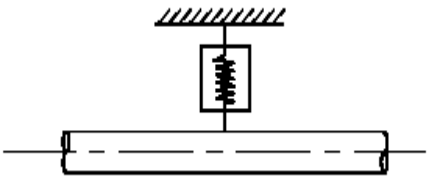
- ***Saddle support :-*** saddle type is used to support bigger insulated pipes 10" & above. it is used as a guide support

- ***Trunnion support.***

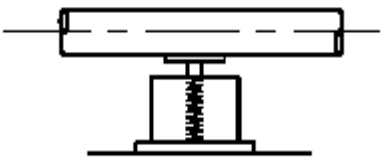


In this type of support a dummy pipe piece is welded directly to the main pipe & other end is suitably supported on the secondary support. Trunnion can be either in horizontal or vertical as per the requirement.

- ***Spring support.*** Some time support point may move up or down due to thermal expansion or vibration in the system. The system employs a spring elements, which can get compressed or released depending upon the load exerted on it. Spring support can either be resting or hanger type.

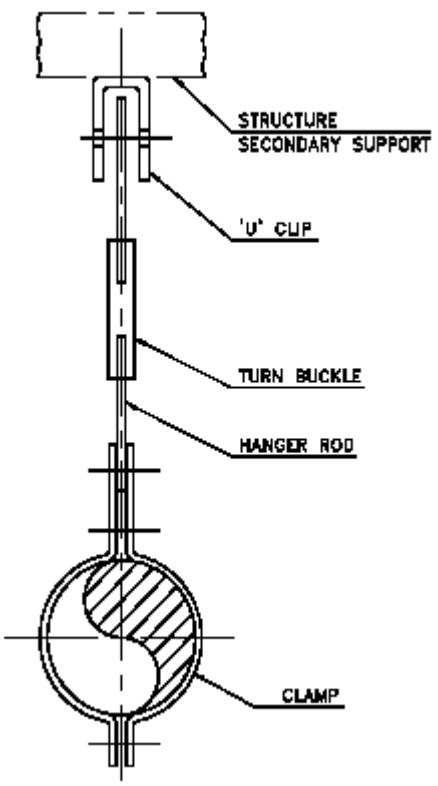


HANGER TYPE



RESTING TYPE

- ***Hanger support.***



As the name suggest in hanger support pipe is hung from the overhead structure using the hanger rod.

- ***U- Bolts :-*** This is most simplest & extensively used pipe support for non insulated piping these are generally used as guide.

GENERAL CONSIDERATION FOR DIFFERENT PIPING SYSTEM:

UN-INSULATED C.S. PIPING :

- The un-insulated carbon steel pipe (bare pipe) generally rests directly on the secondary support.
- Large bore pipes generally NB ≥ 14", a pad is needed to avoid deformation in pipe at support.
- Generally U-bolts can be used at guides. Guide lugs can also be used.

UN-INSULATED S.S. PIPING :

- The un-insulated, stainless steel pipe do not rest directly on the secondary supports.
- Shoe type support with clamp of carbon steel is used for support.
- A thin stainless steel sheet or an asbestos cloth is used between pipe and clamp.

HOT INSULATED C.S. PIPING :

- The hot insulated C.S. Piping never rests directly on secondary support.
- Shoe type support of carbon steel with or without clamp is used.
- U-bolts are not used.

HOT INSULATED S.S. PIPING :

- The hot insulated stainless steel piping will generally use shoe type support of carbon steel with clamp.
- A thin stainless steel sheet or an asbestos cloth is used between pipe and clamp.
- When welded type shoe is required, then the pipe shall have an S.S pad welded to pipe. The C.S. shoe shall be welded to S.S. pad.

HOT INSULATED ALLOY STEEL PIPING :

- The hot insulated Alloy Steel piping shall generally use shoe with clamp.
- When ever essential, welded type shoe can be used.
- The material of clamp and shoe shall be carbon steel or alloy steel depending on the pipe temperature.

COLD INSULATED PIPING :

- Cold insulated piping generally use pipe shoe with clamps of carbon steel.
- Pipe shoe with clamp, put directly on the cold pipe will need special insulating blocks between pipe shoe base plate and the secondary support member.
- The support material needs to be compatible with the pipe temperature.

PLASTIC PIPING :

- Plastic being a weak and soft material therefore the pipe supports used for plastic piping, necessarily employ a clamp-shoe assembly (of carbon steel) with a soft PVC sheet in between pipe and clamp.

PIPE SUPPORT SPACING CHART

NOMINAL PIPE SIZE	**SUGGESTED MAX SPAN**			
(NB)	**WATER SERVICE**		**STEAM, AIR ,GAS SERVICE**	
	(METERS)	(FEET)	(METERS	(FEET)
1	2.1	7	2.7	9
2	3.0	10	4.0	13
3	3.7	12	4.6	15
4	4.3	14	5.2	17
6	5.2	17	6.4	21
8	5.8	19	7.3	24
12	7.0	23	9.1	30
16	8.2	27	10.7	35
20	9.1	30	11.9	39
24	9.8	32	12.8	42

CALCULATION FOR PIPE SUPPORT SPACING

N = √ZS/4Wf

Where **N -** allowable spacing in feet
Z - section modulus of pipe in inches
S - allowable stress (¼ of allowable stress valves)
Wf – weight of line full of liquid plus insulation & permanent load,ibs/ft

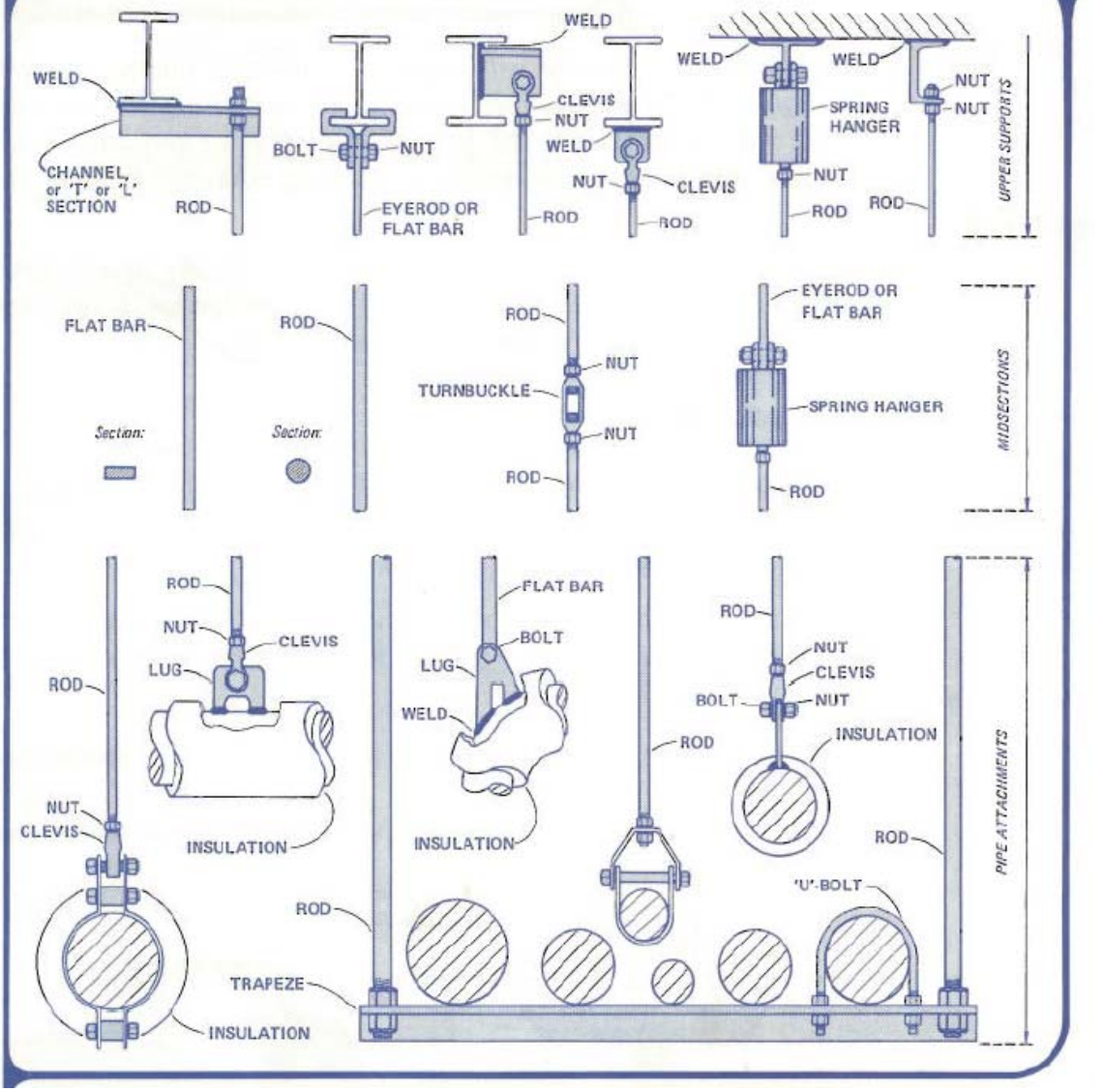
GUIDE LINES FOR LOCATING PIPE SUPPORTS

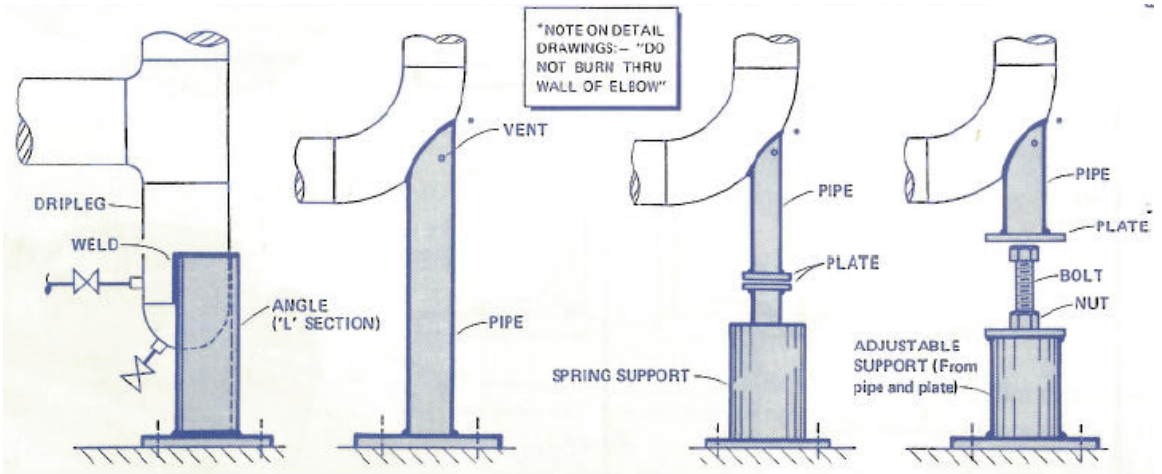
- Support should be located as close as possible to the concentrated loads so that the bending moments is minimum.

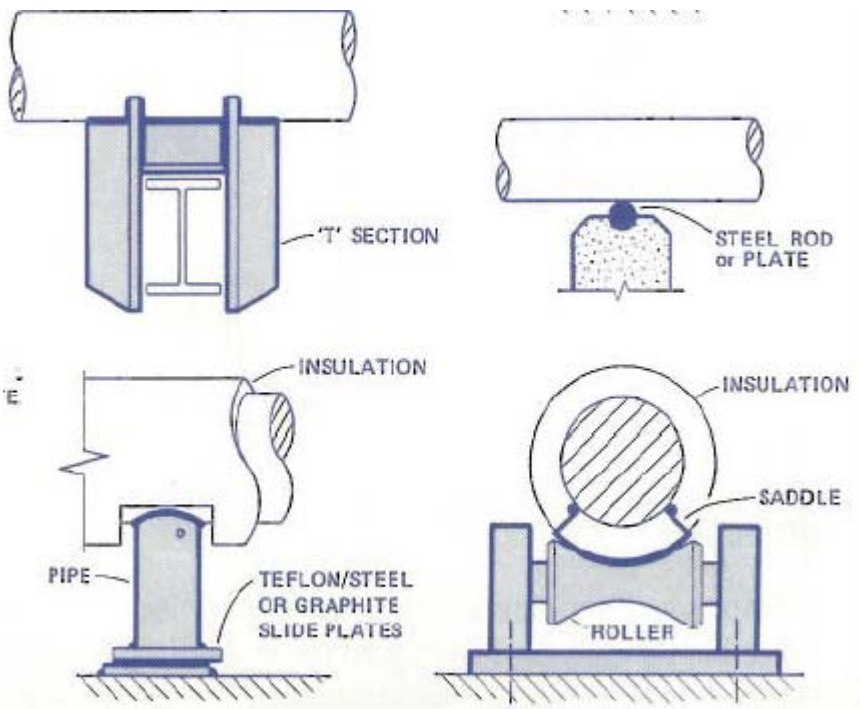
- When there is change in direction the tabulated support spacing value should be limited to 75% to reduce eccentric load.

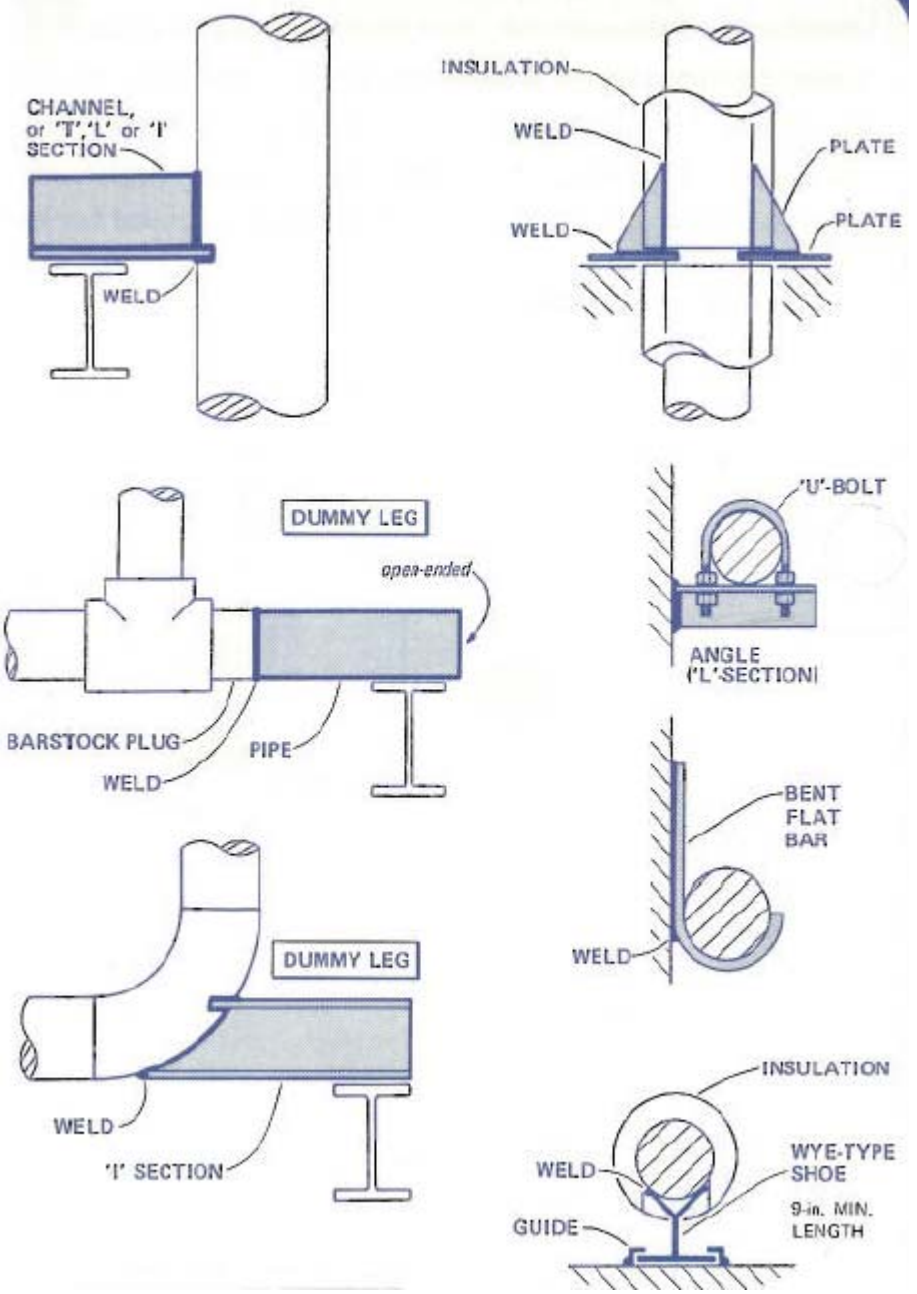
- In vertical pipe run there will be no moment & stress developed. To ovoid sagging by its own weight & wind long vertical run pipes runs are supported by guides at a span twice the normal horizontal span.

HANGERS


WELD
CHANNEL or 'T' or 'L' SECTION
ROD
BOLT
NUT
EYEROD OR FLAT BAR
WELD
CLEVIS
NUT
WELD
ROD
NUT
CLEVIS
ROD
WELD
WELD
NUT
NUT
SPRING HANGER
NUT
ROD
ROD
UPPER SUPPORTS
FLAT BAR
Section:
ROD
Section:
ROD
NUT
TURNBUCKLE
NUT
ROD
EYEROD OR FLAT BAR
SPRING HANGER
ROD
MIDSECTIONS
ROD
NUT
CLEVIS
LUG
ROD
NUT
CLEVIS
INSULATION
ROD
TRAPEZE
INSULATION
FLAT BAR
BOLT
LUG
WELD
INSULATION
ROD
ROD
NUT
CLEVIS
BOLT
NUT
INSULATION
ROD
'U'-BOLT
PIPE ATTACHMENTS


*NOTE ON DETAIL DRAWINGS:– "DO NOT BURN THRU WALL OF ELBOW"
DRIPLEG
WELD
ANGLE ('L' SECTION)
VENT
PIPE
PIPE
PLATE
SPRING SUPPORT
PIPE
PLATE
BOLT
NUT
ADJUSTABLE SUPPORT (From pipe and plate)


'T' SECTION
STEEL ROD or PLATE
INSULATION
PIPE
TEFLON/STEEL OR GRAPHITE SLIDE PLATES
INSULATION
SADDLE
ROLLER


CHANNEL, or 'T', 'L' or 'I' SECTION
WELD
INSULATION
WELD
PLATE
WELD
PLATE
DUMMY LEG
open-ended
BARSTOCK PLUG
WELD
PIPE
'U'-BOLT
ANGLE ('L'-SECTION)
BENT FLAT BAR
WELD
DUMMY LEG
WELD
'I' SECTION
INSULATION
WELD
WYE-TYPE SHOE
9-in. MIN. LENGTH
GUIDE